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ESSAYS IN MACROECONOMICS AND HOUSING

BY

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DISSERTATION

Submitted in partial fulfillment of the requirements
for the degree of Doctor of Philosophy in Economics
in the Graduate College of the
University of Illinois at Urbana-Champaign, 2016

Urbana, Illinois

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ABSTRACT

In the first chapter, we unveil a feedback loop between monetary policy, housing tenure choice (own vs rent) and measured inflation and quantify its consequences. This feedback loop is explained in three parts: i) Housing rents respond positively to contractionary monetary policy shocks; ii) This effect of interest rates on housing rents gives rise to an important and systematic inflation mismeasurement problem because, directly and indirectly, housing rents weigh approximately 30% in the CPI and 13% in the PCE; iii) When interest rates are set according to a Taylor rule, the systematic mismeasurement of inflation gives rise to a feedback loop by which the monetary authority keeps setting interest rates too high (low) because inflation is apparently too high (low). To rationalize i) and quantify the importance of iii) we propose a standard New Keynesian model augmented with an endogenous housing tenure choice mechanism. Using a calibrated version of the model, we do a counterfactual exercise and estimate that, when the monetary authority targets the implied consumer price index net of housing rents instead of the implied consumer price index, the loss function of monetary policy is 14.5% lower and the welfare in terms of consumption equivalent variation is 0.9% higher. Finally, analysing the same alternative scenario for the 1983-2006 US experience, we find that the standard deviation of housing prices and nominal inflation would have been 24.8% and 19.9% lower, respectively.

In the second chapter, we provide an alternative explanation for the price puzzle (Sims 1992) based on the effect of monetary policy on housing tenure choice and the weight of the shelter component in overall CPI. In the presence of nominal or financial frictions, when interest rates increase, the real cost of owning a house increases, and this increase may make some people prefer to rent instead of buying. This change in consumption behavior increases the price of rents relative to other goods. Starting in 1983, homeownership costs are based

on a measure of implied owner equivalent rent, which is calculated using observed house rents. This change implies that, directly and indirectly, prices in the rental market almost entirely command the shelter component of CPI, which weighs around 30% in the overall index. When we take these two pieces into account and use CPI net of shelter services as a measure of inflation, we obtain impulse responses of prices to a monetary contraction shock more in line with what is predicted by theory. In addition, our results also suggest that inflation is much less persistent than what is implied by analyses using a measure of inflation that includes shelter services. Our results pass a long list of robustness check exercises and compare well against other explanations of the price puzzle.

Finally in the third chapter, we investigate the observed differences in the service sector's labor productivity between Europe and the US. The objective of this chapter is to identify factors that can explain such differences. Our approach to identify these factors is two-folded. First, we break down the service sector and extend a standard structural transformation model of Duarte and Restuccia (2010) to investigate how the structural transformation within the service sector affects the labor productivity of the service sector. We show that a compositional analyses of the service sector reveals that the differences in the service sector's productivity between different Europe and the US are the result of differences in the labor productivity of trade, food and accommodation, transportation, storage and communication. Second, we explore the EU KLEMS data set to empirically investigate if differences in labor market regulation help explain the differences in the service sector's productivity. Our preliminary results suggest that labor market regulation is negatively correlated with service labor productivity.

To my wife, Glaucia Possas da Motta and my brother, Joao Bruno Duarte.

ACKNOWLEDGMENTS

I wish to express my deepest gratitude to my advisers Dan Bernhardt, Stephen Parente and Daniel A. Dias. They have generously dedicated their time and expertise to guide me through all the steps I needed to take in order to earn a Ph.D. Their role was crucial to keep me focused and set my short- and long-term goals. Without them I could not have completed this dissertation.

In particular, I am very grateful to my mentor, Daniel A. Dias. He has changed the course of my academic career, giving the most valuable professional advice that I have ever had. I have worked with him since an early stage of the graduate school and this relationship has taught me so many priceless lessons.

I would like to express my gratitude to Stephen Parente. His lessons inside and outside the classroom inspired me to become a macroeconomist. Our meetings alone, made my six years in Champaign-Urbana worthwhile. It was a great honor and experience to be his teaching assistant for the macro core course and to have him as our senior faculty leader at the Macro Reading Group. I am very thankful to him for teaching me and openly discussing a broad range of macroeconomics in such a deep and at the same time pleasant way.

I very grateful to Dan Bernhardt. He is my intellectual role model. His academic dedication and sharp thoughts have inspired me to become a better economist during my PhD. Moreover, his guidance and important comments were essential in the process of earning my PhD. I am very grateful for all the time and thought he spent on me and my research.

For their comments and professional advice, I am also grateful to Rui Zhao, Antonella Tutino and Minchul Shin. They have taught to me several valuable lessons that have helped me tremendously in my career. Likewise, I should express my sincere appreciation to In-

Koo Cho.. His classes are just priceless. For comments and suggestions that helped me to improve this dissertation, I am thankful to Chris Sims, Harald Uhlig, Anne Villamil, Woong Yong Park, Igor Ezio, Mark Wright, Alejandro Justiniano and Leonardo Melosi.

I would like to give very special thanks to Professor Werner Baer for his constant effort to support all students at the University of Illinois, including myself. I owe my graduation at the University of Illinois to him since he was the one that made me interested in applying to UIUC during one of his regular visits to Pernambuco in Brazil.

I am also grateful for the support given by Professors Martin Perry, Mattias Polborn and Firouz Gahvari.

It is important to acknowledge the contribution given by friends and colleagues, who have provided fruitful discussions and helpful feedback: Paulo Henrique Vaz and Diloa Athias, who have helped me in every single step of this journey, from the Ph.D. application to the job placement, and Luiz Felipe Sáenz and Cesare Buiatti, who are the co-authors of the third chapter of this dissertation; as well as Rafael Ribas, Breno Sampaio, Gustavo Sampaio, Euler de Mello, Igor Cunha, Rafael Matta, Leandro Rocco, Henrique Fonseca, Diogo Carvalho, Fabricio d'Almeida, Rodrigo Schneider and Gustavo Cortez. It was also an honor to share the same classroom with outstanding students such as Richard Tsay, Luiz Amaral, Bing Zuo, Cong Zhang, Mehrnoush Shahhosseini, Arash Farahani, Thomas Sahajdack, Eduardo Malasquez and German Caruso.

My friends and former advisers, Alexandre Rands and Yony Sampaio, have also contributed to this achievement. Thank you all!

I also want to give a very special thank you note to my friends in Pernambuco that support me at all times and motivate me to continue my research efforts in economics. This group of close friends has a very special name. I thank you Hot Caldinho!

I would like to thank my sister, Ana Duarte Rodrigues, for helping me built a great foundation to carry academic learning successfully.

Nothing would be possible without the support of my brother, Joao Bruno Duarte, who helped in all the highest and lowest moments of my journey towards graduation. Moreover,

his advice, clear mind and connectedness to the private industry allowed me to understand very important issues in economics that sometimes are missed in more formal theoretical analyses.

Finally, I want to thank my wife, Glaucia Possas da Motta, for all her love and support. She was always by my side facing all the challenges that were posed to me (and there were many!). Without her I could not have crossed the finish line. I am very thankful for all her patience in difficult moments and for her amazing spirit in moments of joy. She turned even my darkest moments into happy ones.

This dissertation is dedicated to my wife and my brother.

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CHAPTER 1

HOUSING AND MONETARY POLICY IN THE BUSINESS CYCLE: WHAT DO HOUSING RENTS HAVE TO SAY?

1.1 Introduction

Since the 2007/2008 financial crisis the efforts to better understand the links between housing and the macroeconomy have been enormous and a large amount of new research has been produced since then. The bulk of the literature on housing and the macroeconomy has focused almost entirely on the role of house prices on different economic outcomes such as output, consumption or financial stability. Interestingly, housing rents, which are obviously related to house prices, have been, to the best of our knowledge, completely overlooked.

In this paper, we fill this gap in the literature and unveil and quantify the importance of a new link between monetary policy and the housing market that operates through the effect of monetary policy on housing rents and vice-versa. Before explaining this channel of monetary policy, we must first introduce a new stylized fact regarding the effect of monetary policy on housing rents, and highlight the importance of housing rents in the most commonly used measures of inflation, the consumer price index (CPI) and the personal consumption expenditures (PCE) price index.

New stylized fact: we show housing rents respond positively to contractionary monetary policy shocks using SVAR and FAVAR models and structural shock identification techniques on US data. Specifically, we find that when the federal funds rate is raised by 25 basis points, housing rents increase by 1.22% after five years. Our empirical findings are obtained in the context of empirical models that also include house prices, which were already known to respond negatively to contractionary monetary policy shocks (Iacoviello (2005), Del Negro

Joint work with Daniel A. Dias.

and Otrok (2007)). Hence, it is surprising that housing rents increase when income, other sale prices and housing prices fall after that same unexpected increase in interest rates.

One possible explanation for these two apparently conflicting results, house prices declining while house rents increase in response to a contractionary monetary policy shock, is the effect that monetary policy may have on housing tenure decisions (own vs. rent). If for some reason the prices of houses and rents do not adjust quickly enough to its new long-run nominal level after a contractionary monetary policy shock, the relative costs of owning vs. renting will change, and this will lead to some people switching from one type of tenure to the other. In support of this interpretation, we show that after a contractionary monetary policy shock rental vacancy rates, homeownership rates and housing starts decline while homeowner vacancy rates increase.

Importance of housing rents in the CPI or PCE: since the adoption of the owner equivalent rent (OER) estimate in 1983 as a measure of shelter costs faced by homeowners that live in their own house, that the direct and indirect weight of housing rents in the CPI has been over 20%, and currently surpassing 30%. In the case of PCE, which uses the same information coming from the housing rental market, the current weight of shelter in the overall index is lower than in the case of CPI and is just slightly above 13% of the total index.¹ The reason why housing rents have such a large weight on total CPI and total PCE is because in the estimation of the OER the Bureau of Labor Statistics (BLS) uses information from the housing rental market to impute rental prices to houses that are owner-occupied (see BLS CPI methodology (2009) for more details on this procedure). Reflective of this is the fact that the correlation between the year-on-year growth rates of housing rent and OER is around 0.85. Hence, the shelter component of CPI and PCE is almost entirely driven by the housing rental market.

The new channel of monetary policy that we claim to unveil is as follows: when the monetary authority increases (decreases) interest rates, *real* housing rents increase (decrease). This creates a measurement issue in tracking underlying nominal inflation and leads to a

¹If we excluded the food and energy components from CPI and PCE, that is, if our reference was not total CPI or total PCE but core CPI and core PCE, the current weights of shelter in core CPI would be over 40% and over 17% in the case of core PCE.

downward (upward) biased estimate of inflation when CPI or PCE are used. Because directly and indirectly, housing rents have a fairly large weight on CPI and PCE, this bias may be sufficiently large and lead the monetary policy authority to keep setting interest rates too high (low) in its attempt to achieve a certain inflation target. This feedback can add unnecessary variation to the underlying inflation rate and housing prices, and generate large welfare costs and losses to a monetary policy whose objective is to minimize inflation and output gap variance.

To formalize and quantify the importance of this mechanism we add an endogenous housing tenure choice mechanism and heterogeneous agents to a standard New Keynesian model (Clarida et al., 1999). By including housing rents, we can introduce a theoretical CPI in the model that is constructed based on a weighted basket of housing rents and composite consumption good. We calibrate the model to match key features of the U.S. economy assuming the monetary authority reacts to CPI, and show that it fits remarkably well some of the data moments that are not targeted by the calibration exercise. Moreover, with our model, we are able to endogenously generate a price puzzle without having to assume that there is a cost channel of monetary policy.²

With the calibrated model we do a counterfactual exercise where we compare both aggregates and price dynamics of the calibrated model, the benchmark case, whereby we assume the interest rate Taylor rule takes CPI as input, to an alternative setting where the Taylor rule takes a rents-free consumer price index as input. Our counterfactual exercises reveal that: 1) targeting a measure of inflation that excludes housing rents leads to a 0.9% welfare gain in consumption equivalent variation and to a 14.5% fall in the loss function of monetary policy whose objective is to minimize inflation and output gap variance; 2) we estimate that this mechanism can explain 37.5% of the increase in house prices above trend³ that occurred between 2002 and 2007; 3) under the alternative scenario, we find that the standard devia-

²In a companion paper, Chapter 1 of this monograph, we explore this result further, and show that to a large extent the price puzzle can be explained by the response of shelter to monetary shocks. In addition, we also show that inflation is much less persistent than what analyses based on overall CPI or PCE suggest.

³The trend was computed using an HP filter. It is worth noting our model is a business cycle model and has nothing to say with respect to housing prices trend. Although the trend of housing prices was substantial between 2002 and 2006, we can still analyse by how much housing prices were above trend for the same period and compare this housing prices business cycle dynamics for the two different scenarios.

tion of housing prices and nominal inflation would have been 24.8% and 19.9% lower for the 1984-2006 US experience, respectively.

In this paper, we do not argue for the exclusion of housing rents from the CPI in every circumstance. Housing rents are an important item on measuring households cost of living since households spend around 30% of their income with shelter, and hence should be part of the consumer price index. In general, price indexes trends capture well the evolution of the nominal state of the economy. However, when relative prices of some specific goods change suddenly, these price indexes are affected regardless of how underlying monetary inflation behaves. Vining and Elwertowski (1976) make this point very clearly. This is one of the reasons economists have built core versions of the price indexes. When studying the effects of monetary policy on the monetary inflation, it is important to remove housing rents, thus creating a different core index, because their relative price is strongly affected and they have a large weight in price indexes. When these two facts are added together, serious biases can be introduced when tracking the nominal state of the economy.

Our contribution adds to three distinct strands of literature, namely the literature looking at housing and the business cycle, the literature about problems of the CPI, or similar price indexes, as a measure of inflation, and literature about housing tenure choice. The two papers about housing and the business cycle that are closest to our contribution are Iacoviello (2005) and Leamer (2007). In Iacoviello (2005), the author makes the point that housing market generate amplifications of the business cycle dynamics because housing prices are used as collateral and they co-move with the economy activity. In our paper, we abstract from the housing prices financial channel and focus on explaining how housing rents can also lead to business cycle amplifications through mismeasurement in the CPI coupled with a Taylor rule. In Leamer (2007), the author argues that “housing is the business cycle” and proposes that the monetary authority should not only target inflation and GDP, but also housing starts. In this paper we incorporate this suggestion indirectly because by better controlling (true) inflation, the monetary authority is also indirectly controlling the incentives for investment in housing.

In the case of the literature on the problems of CPI as measure of inflation, we add to the literature on measures of core inflation – the issue we highlight is due to a change in relative

prices – but also to the literature on the biases of the CPI as measure of inflation. In the case of core inflation, the list of contribution is very long and therefore the best reference is a survey paper like Clark (2001) which summarizes the main contributions in this area. In the case of biases of the CPI as measures of inflation, the starting point of this literature is Boskin et al. (1998). In this paper, the authors estimate that due to different sources, the CPI is biased upwards by more than 1 percentage point. Moreover, specifically analysing how shelter is computed in the CPI, Gordon and vanGoethem (2007) argue rental shelter housing has been biased downward for its entire history since 1914, while Díaz and Luengo-Prado (2008) show that the rental equivalence approach overestimates the cost of housing services. An important distinction of our paper to this literature is that we show a dynamic bias in the CPI instead of a static one.

To the best of our knowledge, the first model of housing tenure choice was developed by Henderson and Ioannides (1983). However, their analysis is in a partial equilibrium setting. More recently, Chambers et al. (2009) have expanded the structure of the rental and housing markets and were able to show mortgage innovations in the U.S. account for most changes in homeownership rate. Sommer et al. (2013) take Chambers et al. (2009) structure and are the first to consider a model where both housing rents and housing prices are determined in equilibrium. However, Sommer et al. (2013) analysis is for steady state and transitional dynamics. In our paper, at the cost of extremely simplify the structure on the housing and rental market, we are able to endogeneize housing rents and housing prices in the business cycle.

The remainder of the paper is organized as follows. In section 1.2 we provide our main empirical findings which show the effect of monetary policy on housing rents and housing tenure choice. Section 1.3 builds the monetary model and section 1.4 calibrates the model to the US experience and discusses the model solution. Section 1.5 shows the counter factual exercise with the calibrated model. Finally, section 1.6 draws the main conclusions of the paper.

1.2 Empirical Findings

1.2.1 Evidence on the effect of monetary policy on housing rents and prices

In this section we describe the data used and show the impulse responses of the variables of interest to a contractionary monetary policy shock using SVAR and FAVAR. The monetary contractionary shock is defined here as an unexpected increase in the federal funds rate.

Our main finding is that housing *rents* respond positively to a contractionary monetary policy shock. This response is surprising as housing *prices*, most other sale prices and output respond negatively to the same shock. Moreover, the response is large in magnitude. In our benchmark SVAR, we find that a permanent increase of the federal funds rate by 25 basis points increases housing rents by 1.22% after five years.

1.2.1.1 SVAR

A. SVAR Data and Identification

The data used in the SVAR covers the 1975-2006 period for the US. The starting period was selected based on when housing prices data became available. We exclude the period of the great recession because the standard monetary transmission mechanism was lost during the period. Hence, interest rate Taylor rule behaviour was no longer a good description of monetary policy in the neighbouring period of the great recession. For this reason, we excluded the period from our analysis.

All data was collected from FRED database. We used six aggregate time series for the US in our SVAR analysis: real gross domestic product (GDPC1), all-transactions house price index (USSTHPI), rent of primary residence in CPI (CUS-R0000SEHA), GDP deflator (GDPDEF), M1 money stock (M1) and finally federal funds rate (FF). Real housing prices and rents were computed deflating the housing price index and rents with the GDP deflator. All series were transformed to be covariance stationary using log-difference with the exception of federal funds rate. This transformation also allows for an easier interpretation of the impulse-response functions.

The SVAR is an appropriate empirical strategy to analyze the dynamic impact of monetary policy on housing rents as it allows one to identify a monetary policy shock with a small set of assumptions. In our benchmark SVAR, we use the standard Cholesky identification following Christiano et al. (1998) whereby the order follows GDP, Inflation, Housing rents, housing prices, federal funds rate and M1. Hence, monetary policy instruments are ordered last and have no contemporaneous effect on the remaining variables of the system.

However, the ordering of the variables in the system is always a cause of concern. In this particular case, matters become worse because how can one order housing prices and rents? However, our main results are robust to different orderings in the Cholesky decomposition. In addition, our results are also robust to a different identification strategy by pure-sign restriction following Uhlig (2005). In the pure-sign restriction we restrict the response of inflation to be negative, M1 to also be negative and federal funds rate to be positive for four periods while the remaining responses are left unrestricted.

B. *SVAR Results*

Our main finding is housing rents increase after a monetary contractionary policy shock. In addition, we show housing prices decrease in response to the same shock. While the result on housing prices confirms previous findings in the literature like in Iacoviello (2005) and Del Negro and Otrok (2007), the housing rents positive response is novel and surprising.

In Figure 1.1, we show the responses of our six variable benchmark SVAR to a positive standard deviation shock in the federal funds rate. All the responses are in percentage points on the level of each variable. Housing rents responds positively after six quarters forward. The initial sluggish response of housing rents could be the result of stickiness, as housing rents contracts are usually annual.

The effect of the monetary policy contractionary shock on housing rents is long lasting, reaching an approximately 0.4% positive response after twenty quarters, five years. The response is large in magnitude and although not reported here, the response is also significant at a 95% credible set. If we calculate the accumulated effect on housing rents, we find that

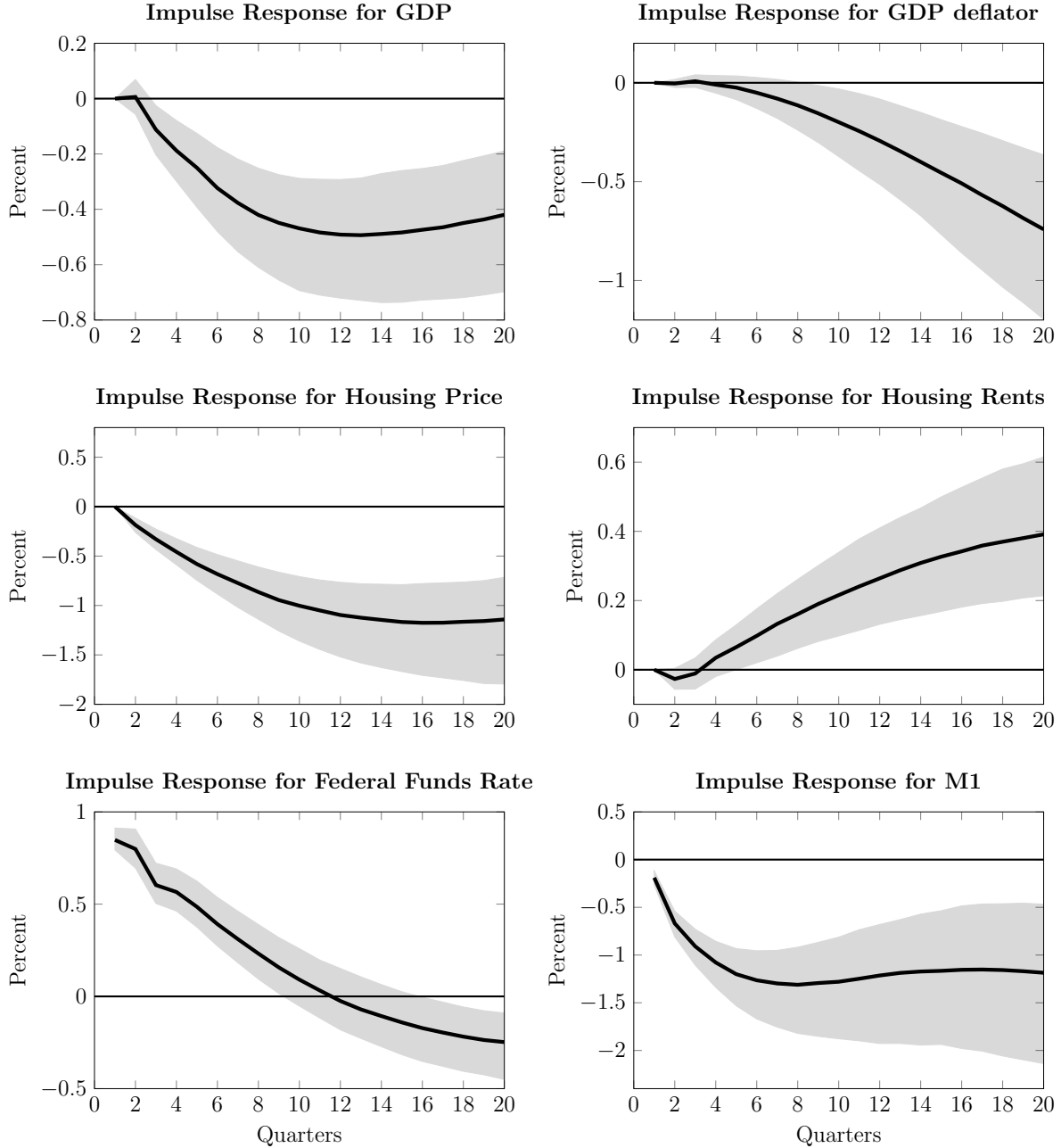


Figure 1.1: Recursive identification Impulse Responses and confidence bands of the SVAR system to a standard deviation shock in the federal funds rate. Confidence bands represent the 68% credible set of point estimate impulse responses.

a permanent increase of the federal funds rate by 25 basis points increases housing rents by 1.22% after five years.

The positive response of housing rents happens while output, price level and housing prices are decreasing. In particular, we find the usual u-shape response of output to a contractionary

monetary policy shock and that housing prices respond in a larger magnitude than rents in the opposite direction. The negative effect we find of monetary policy on housing rents confirms previous literature findings, like Del Negro and Otrok (2007).

One might worry about the specific order selected in the Cholesky decomposition to identify the SVAR. Hence, as a robustness check we estimate the SVAR with different orders and with an agnostic identifications strategy following Uhlig (2005). The results for the pure-sign restriction are reported in Figure 1.2. In the pure-sign identification we restrict the response of inflation and M1 be negative and federal funds rate to be positive for four periods while the remaining responses are left unrestricted.

The impulse-responses to the contractionary monetary policy shock using the pure-sign restriction are qualitatively the same as what we found in the SVAR with the Cholesky decomposition. In particular, we also find housing rents increase while housing prices fall. However, the responses are larger in magnitude in the pure-sign restriction. Here, the standard deviation shock in the federal funds rate is approximately 0.24%, which is close to what is reported in Uhlig (2005), while the standard deviation in the benchmark SVAR was 0.86%. After accounting for the standardization of the impulse-response functions (dividing the responses by the standard deviation) we find that the response of housing rents to a 1% increase in the federal funds rate is 0.46% and 0.83% in the Cholesky decomposition and pure-sign restriction, respectively.

1.2.1.2 FAVAR

A. FAVAR Data and Identification

The FAVAR methodology provides a solution to the limited information problem of the SVAR, and shows that the added information it exploits helps in properly identifying the monetary transmission mechanism. We use quarterly data on 114 time series, that include a broad measures of prices, production, housing and business activity⁴ like in Stevanovic

⁴We thank Dalibor Stevanovic for kindly providing us with the dataset

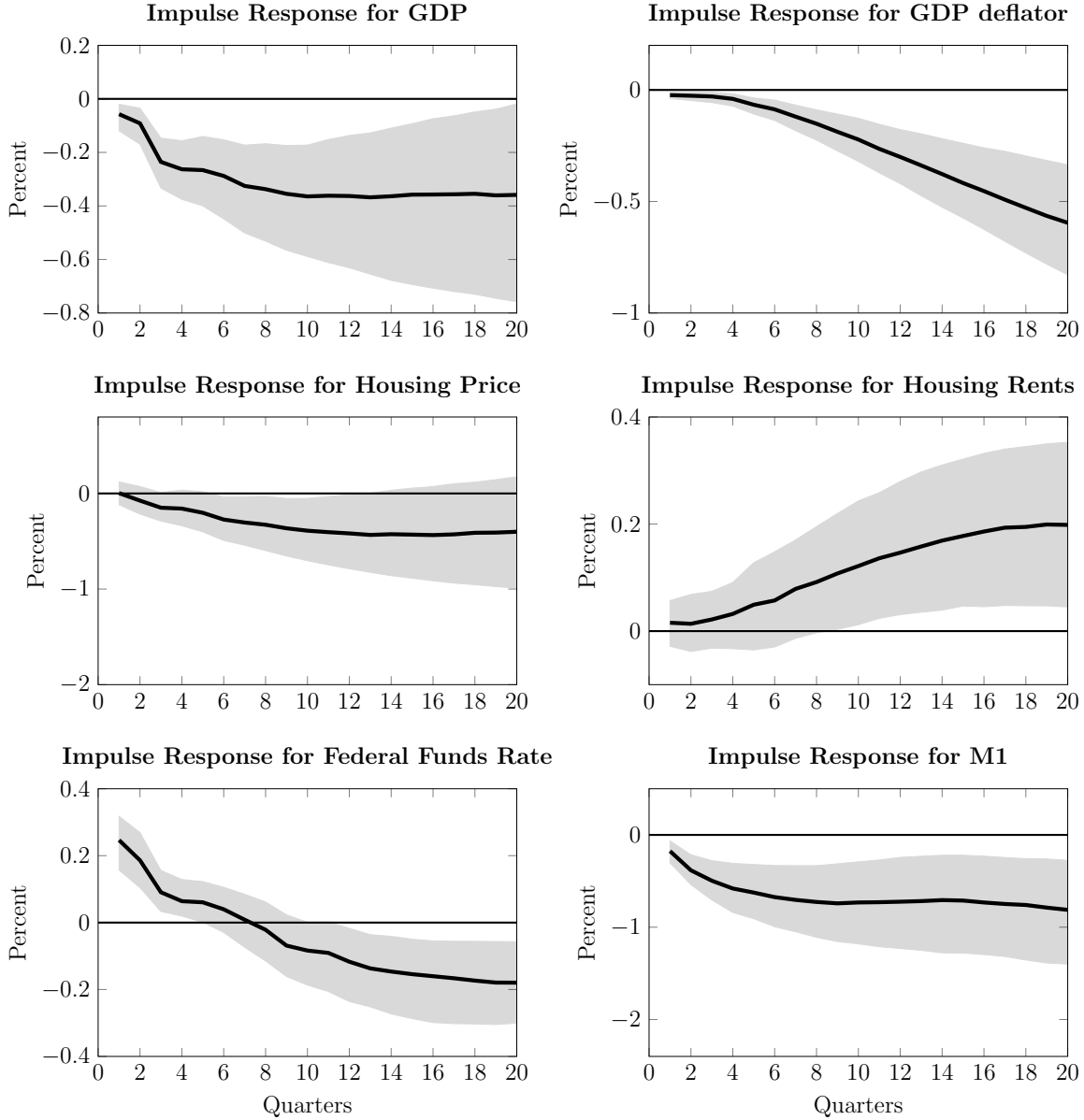


Figure 1.2: Pure-Sign Restriction with $k = 4$ Impulse Responses and confidence bands of the SVAR system to a standard deviation shock in federal funds. Confidence bands represent the 68% credible set of point estimate impulse responses. Here House Prices and Rents are left unrestricted.

(2015) Stevanovic (2015) plus our variables of interest over the 1959Q1- 2006 Q4. All data are assumed stationary or transformed to be covariance stationary⁵.

We follow Bernanke et al. (2005) and first use principal components analysis to construct three factors that provide information about the underlying state of the economy. Secondly,

⁵The principal components analysis requires the data is all in a similar scale and is stationary

we treat the Federal funds rate (FFYF) as an observed factor and estimate a SVAR with four variables: the federal funds rate plus the three factors we estimated using principal components.

The FAVAR naturally allows to overcome missing data. We replace the missing values with the mean of each variable and use principal components to estimate the factors with the full dataset. There is no clear way on how one should proceed when dealing with missing data, since not including the full sample period when data is available to most of the variables can also create bias. In our case, the factors estimation will not be adversely affected by the missing data since it amounts to only 1.6% of the total data. At the same time, the benefits of adding more information on all other series are rather large. Hence, we decided to estimate the full sample. Nonetheless, the results are robust if we use 1983-2006 sub-sample period only.

Another interesting feature of the FAVAR is that we can recover the impulse-responses functions of any of the data series we are interested in, through the effect of the shock on each factor. This is made possible by the principal components analyses that decomposes all series by how much they are explained by factors and by what is unknown. Hence, using the loading factor coefficients we can then recover the effect of a contractionary monetary policy shock in any variable of interest.

B. *FAVAR Results*

The FAVAR results confirm our SVAR findings while arguably having a better identification of the contractionary monetary policy shock. In Figure 1.3, we present the impulse-response functions of the variables that constituted the benchmark SVAR to allow an easier comparison between the two results. Housing rents respond positively to an unexpected increase in the federal funds rate, while all other sale prices, housing prices and output are falling. Here, the u-shape of output response is clear and this confirms the neutrality of monetary policy in the long-run.

Housing rents response is initially less sluggish than in the benchmark SVAR but it still only starts increasing at a higher pace after three to four quarters. Housing prices again

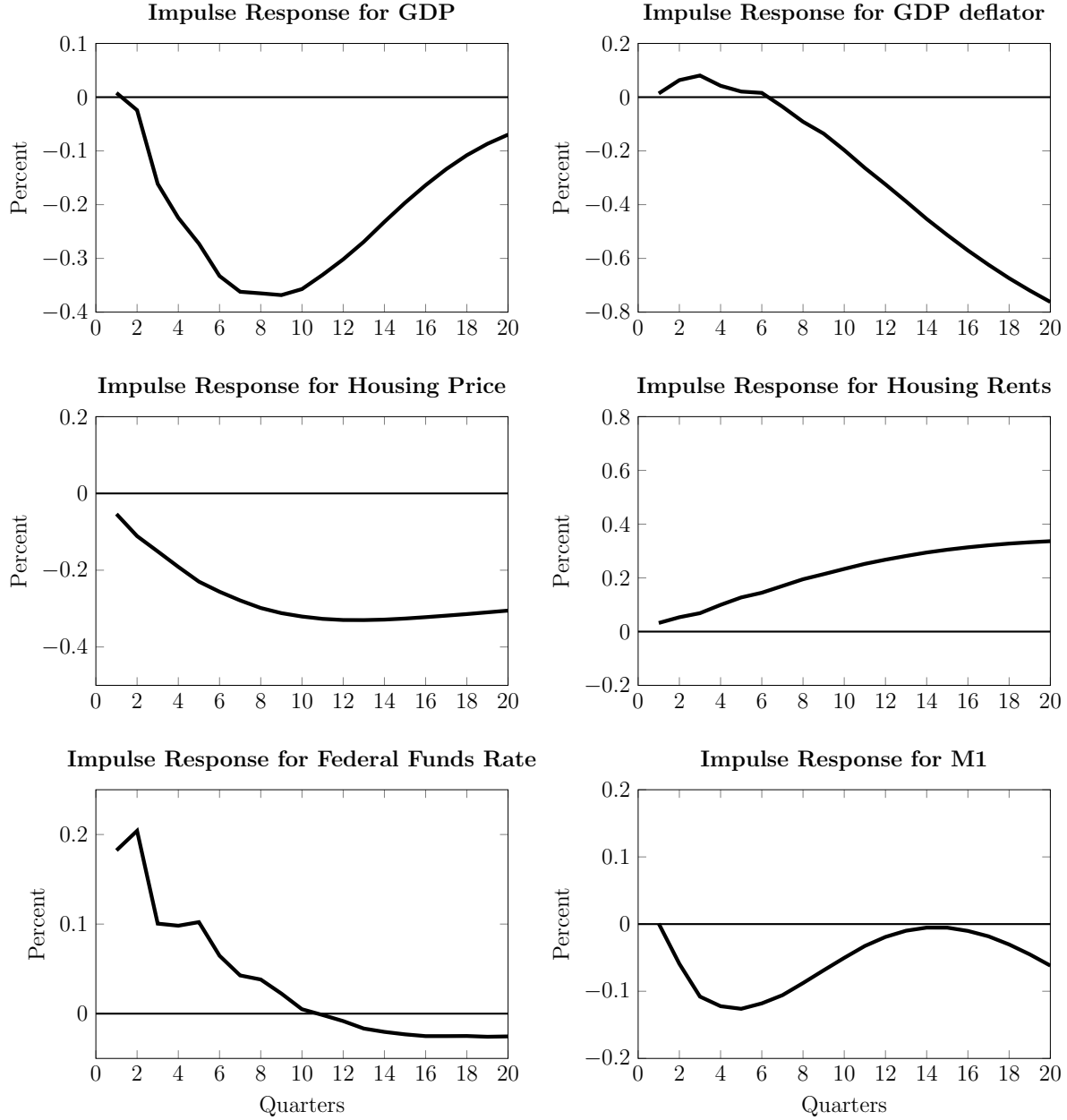


Figure 1.3: FAVAR impulse-responses of variables that constituted the benchmark SVAR to a standard deviation shock in the federal funds rate.

respond in a faster fashion than housing rents. The magnitude of responses is hard to infer directly from the scale reported in Figure 1.3 since all variables were standardized in order to use the FAVAR methodology. Since, we use the FAVAR just as more of a robustness exercise, we are more interested in the qualitative behaviour of the impulse-response functions.

To put it in a nutshell, our main empirical findings on the effect of monetary policy on

housing rents are housing rents increase after a contractionary monetary policy shock. This result is surprising and motivates the question on what market mechanism is behind such price dynamics.

We suggest the effect of monetary policy on housing tenure choice, that is, the choice between owning and renting, can rationalize our empirical findings. In the presence of nominal or financial frictions, when nominal interest rates increases, the real interest rate increases as well and the real cost of owning relative to renting increases. Given everything else equal, this may make some people that are close to be indifferent to prefer to rent instead of buying. If housing supply remains constant or decreases, this change in consumption behavior leads to an increase of housing rents relative to all other goods in the economy while all other prices and income fall. We test if the implications at the aggregate level of such a mechanism are present in the next section.

1.2.2 Evidence on the effect of monetary policy on housing tenure choice

In order to test if the housing tenure choice mechanism is present we show what are the effects of monetary policy on homeownership rate, homeowner vacancy rate, rental vacancy rate. Again, we use SVARs and FAVARs to address this question.

In the SVAR, we add these three variables to the benchmark system and re-estimate the model. By adding all of these variables, we quickly lose a large number of degrees of freedom which highlights some of the limitations of SVARs. In addition, how to order these additional variables is hard to answer. The results are presented in Figure 1.4. The responses of rental vacancy rate and homeownership rate turn out to be non-significant. Moreover, although housing rents behave similar to what we find in the benchmark case, the same cannot be said about housing prices. With the extended SVAR, housing prices are also not significant. The FAVAR methodology allows one to overcome these limitations.

In Figure 1.5, we present the response-functions on variables that are related to the housing tenure choice plus some other variables of interest that are commonly reported in other studies that use FAVARs. All the results confirm the effect of monetary policy on housing

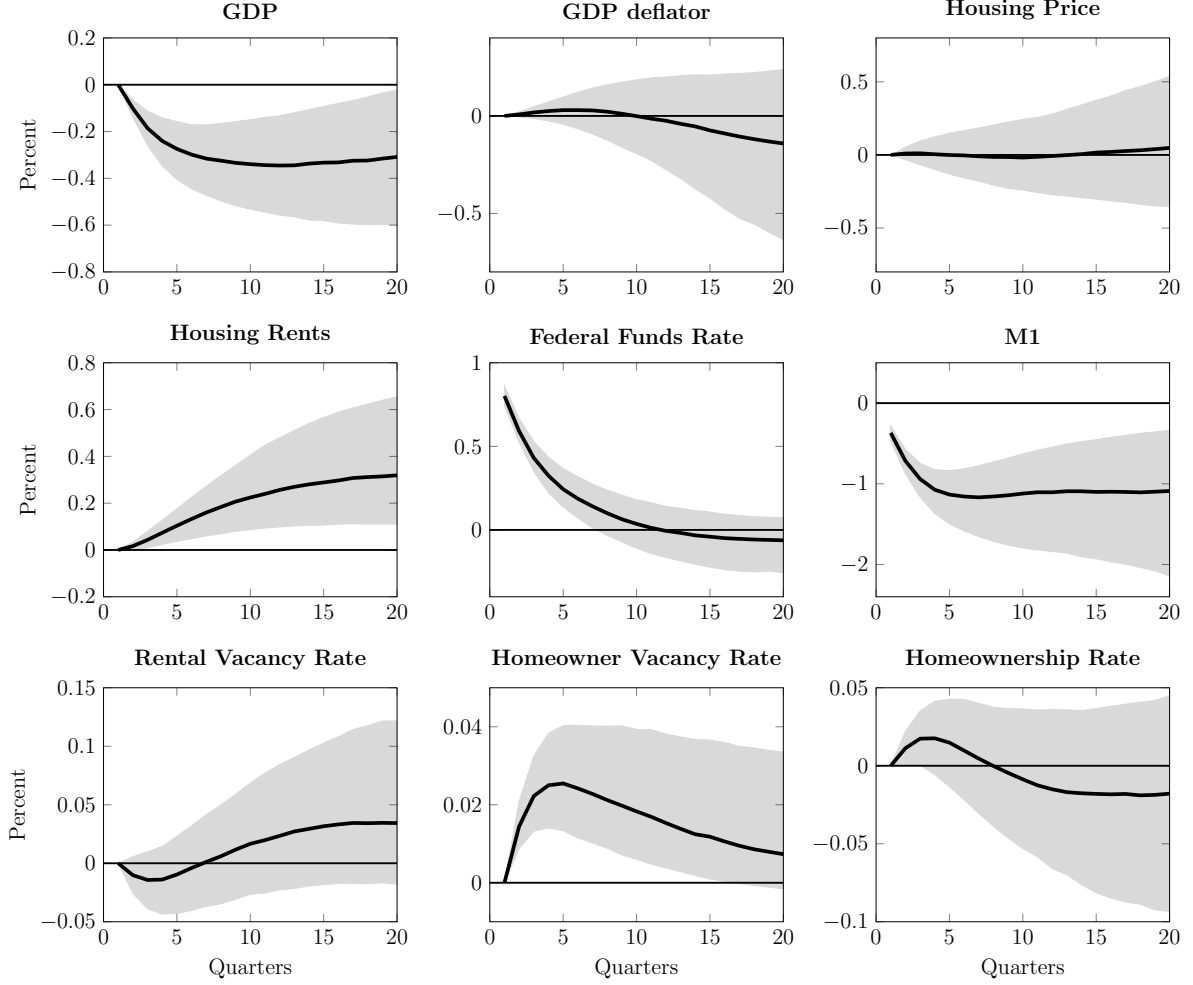


Figure 1.4: Recursive identification Impulse Responses and confidence bands of the extended SVAR system to a standard deviation shock in the federal funds rate. Confidence bands represent the 68% credible set of point estimate impulse responses.

tenure choice. Although, confidence intervals are not reported here yet, a preliminary one step bootstrap confirmed that all of the responses are significant at a 68% confidence level.

We find homeownership rate decreases, which confirms at the aggregate level that more households decide to rent instead of own a house after an unexpected increase in interest rates. Moreover, we also find the rental vacancy rate decreases, suggesting that there is a demand pressure on housing rents and that supply does not seem to keep up making vacancies decrease over total supply of housing rental. At the same time, the opposite is true to homeowner vacancy rate. Finally, similar to previous literature Bernanke et al. (2005), we also find that housing starts decrease, suggesting that housing prices are not falling because

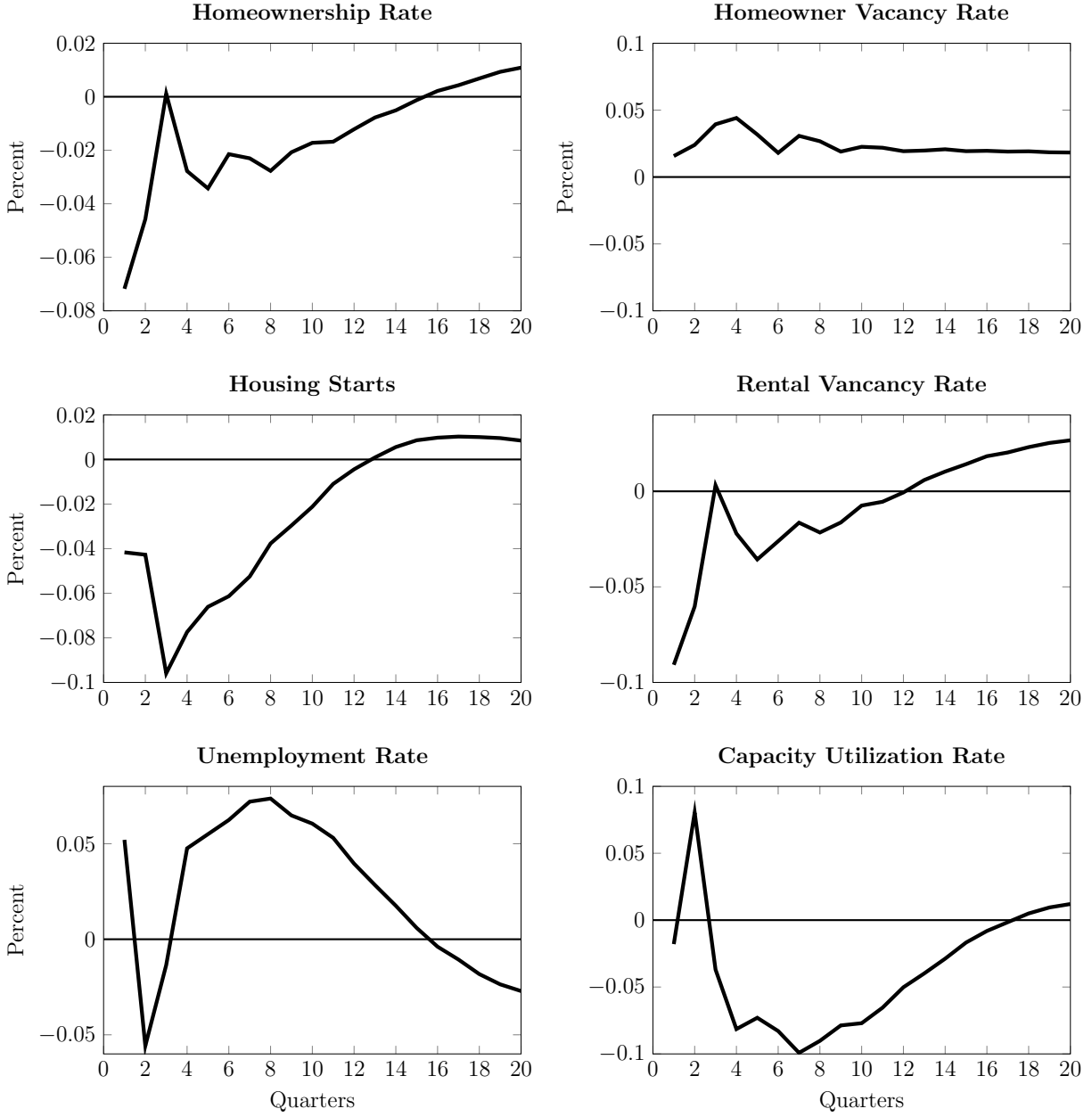


Figure 1.5: FAVAR impulse-responses of housing variables, unemployment rate and capacity utilization rate to a standard deviation shock in the federal funds rate.

of an increase in supply but rather from a strong decrease in housing demand.

1.3 New Keynesian Model with Housing Tenure Choice

We extend Clarida et al. (1999) model with endogenous tenure choice decision, housing prices and housing rents. The inclusion of housing tenure choice in a standard New Keynesian model with Taylor rule allow us to derive implications of monetary policy shocks to both housing prices and rents as well as on homeownership rate. Moreover, by including housing rents, we can introduce a theoretical CPI in the model that is constructed on housing rents and composite consumption good. By assuming that a central bank reacts to an imperfect measure of inflation like CPI, we show how different feedback between inflation and monetary policy is created in a Taylor rule that responds to CPI instead of inflation. In our model, housing rents increase when interest rates increase. Hence, central banks over reacts to inflation shocks when they observe an imperfect measure of inflation like a consumer price index. This effect is worse the larger the share of housing rents in the consumer price index.

Consider an economy where there is a continuum of households with measure one that live infinitely and that from time to time make a discrete decision on weather to own or rent a house when they go to the housing market. There is a fixed probability of re-optimizing on whether to rent or own a house. This probability is assumed to be the same across all agents, both renters and home owners. Therefore, a constant mass of households are going to re-optimize every period. Given, that the mass of households has measure one, the amount of households that re-optimize is just the probability of re-optimizing. This idea is close in spirit to Calvo (1983), whereby a fixed share of firms are allowed to re-optimize every period.

Households are heterogeneous with respect to their preference on the housing services coming from owning a house. Some agents prefer more than others to live in a house they own instead of a rented one. This assumption is commonly assumed in the tenure choice literature. We assume that every period each agent has an *iid* draw from the uniform distribution. The heterogeneity is needed in order to generate households that rent and households that own their house. There are alternative ways to introduce heterogeneity in this model that give the same qualitative implications on the dynamics of the model. Two examples are different households expectations about future housing prices and heterogeneity in maintenance costs when owning a house. These alternatives complicate the solution

without affecting the results.

We assume that in the initial period of the world only a share of the households are endowed with housing stock. Moreover, the households that receive housing stock will have initial high debt so that the initial income is the same across all households. In other words, in the initial period, some households have housing stock to sell but high debt, and others have no initial housing stock and no debt. Moreover, besides the deciding whether to own or rent a house, agents can fully insure against aggregate shocks. This assumption helps isolating the effects coming from heterogeneity in the housing market and it makes the model trackable. The interaction of income distribution and housing distribution would make the model more complicated to solve as we need to keep track of both distributions over time.

The set of assumptions made in this paper reduces the dimensionality problem while allowing us to capture the main dynamics of household heterogeneity in the housing market and how this heterogeneity affects the price dynamics in the housing market. Given income is the same and that decisions, besides the discrete choice, are not affected by the heterogeneity in households preferences, we can go from infinite types ex-ante to only two types ex-post. A household type that rents and other that owns the housing stock. However, the quantity of each type is still endogenous and that is the main difference to standard models in the literature.

Following Iacoviello (2005) we assume there is a fixed stock of housing in this economy. Moreover we assume the shares of the the total stock that is devoted to rent and owning are also fixed. By doing so, we abstract from the supply side when we analyse the price dynamics. There are two main reason that makes one more comfortable with such assumption. First, empirical evidence on the supply side of housing shows the supply of housing decreases when interest rates increase, which would make the impact of interest rate on housing prices and rents stronger. The second reason is we are mainly interested in the dynamics of repeated sales of housing stock. Our main interest lies on studying how the price of the same housing stock fluctuates over the business cycle.

The stock of houses for owning is owned by the households that bought that housing stock. In this economy, there exists landlords that own the housing stock for rent and rent

it to the households. Landlords take care of maintenance costs and include them in housing rents that are charged to any agent type. Hence, households do not face any maintenance cost when renting a house. We assume all agents have fixed equal shares of the landlords firms and thus receive the same amount of profits coming from renting housing.

In our environment, households go on their respective housing market every period. That is, if you are a renter you go to the housing rental market and decide on how much to rent every period. And if you are a owner, you sell the stock you had from previous period and decide on how much to buy again. However, sometimes the households are going to re-optimize and decide on whether he wants to rent or own a house. There are many reasons why come household would do so, but we abstract from this exercise. Here, we just assume households do not re-optimize every period.

The production side of the economy is similar to Clarida et al. (1999). There is a continuum of intermediate monopolistic firms who produce using labor only and sell their product to be used as an input by the final good firms, and are subject to sticky prices. Final good firms produce using intermediate goods varieties only. The monopolistic intermediate firms on the consumption sector are the source of nominal rigidity while housing prices and rents are assumed to be flexible. Finally, there is a monetary authority that obeys a Taylor rule when setting interest rates.

A. Households

Households decide on how much to consume of the composite consumption good and housing services, and finally on how much to borrow with nominal bonds. Households supply labor inelastically and receive a nominal wage W_t for their total labor. On the one hand. if the household decides to own a house, he pays Q_t for each unit of housing services⁶. On the other hand, if the household decides to rent a house, he pays R_t . Finally, households receive/pay gross nominal interest I_t on their nominal bonds. The households have to choose between renting and owning a house. Once they decide to rent or own

⁶We assume for simplicity that each unit of housing stock provides exactly one unit of housing services.

they are stuck with that decision until they can re-optimize again. Therefore, to make this choice, they compare how much utility they receive from each alternative, and choose the one that yields the highest discounted utility to them. The utility is both discounted by time preference of consumption and the probability of re-optimizing. Let V denote the indirect utility function, the agent will choose to rent or own depending on which choice gives him the highest level of utility.

$$\max_{rent, own} (V_{rent}^*, V_{own}^*)$$

When households decide to rent, note that there is no heterogeneity and hence their decision is the same among the households who decide to rent. Their problem⁷ can be described as:

$$\max_{\hat{c}_t, \hat{h}_t, \hat{b}_{t+1}, N_t} E_0 \sum_{t=0}^{\infty} (\beta)^t (\ln \hat{c}_t + \alpha \ln \hat{h}_t - \exp(\tau_t) \frac{N_t^{1+\eta}}{1+\eta})$$

s.t.

$$\begin{aligned} \hat{c}_t + L_t \hat{h}_t + \hat{b}_t &= a_t \\ a_t &= W_t N_t + \Pi_t + O(owned_{t-1}) \left(\frac{I_t}{\pi_t} b_{t-1} + Q_t h_{t-1} \right) \\ \text{given } h_0, b_0 \end{aligned} \tag{1.1}$$

Where τ is an exogenous preference shock to leisure and a_t stands for the household net worth. The indicator function O takes the value one if he households owned a house in the previous period. If he did, he is going to have a debt associated with that purchase that offsets the value of the house. Hence, we assume that the net worth of the agents who are considering renting is the same regardless of whether the household owned a house or not in the previous period. Also, when renting, households do not own the housing stock and

⁷Under the *iid* heterogeneity assumption, one can show that the optimization problem of the household does no depend on considerations about the possibility of changing the tenure choice decision in the future. For the technical details, see section II in appendix A. We thank Dan Bernhardt for pointing out that the solution for a perfectly correlated heterogeneity takes a different form.

hence cannot sell the housing stock in the next period. In our model, we implicitly assume that landlords take care of any type of maintenance.

Solving for the first order conditions of this maximization problem we get the following Euler equations:

$$\hat{c}_t^{-1} = \beta E_t \left[\frac{I_{t+1}}{\pi_{t+1}} \hat{c}_{t+1}^{-1} \right] \quad (1.2)$$

$$\frac{\alpha}{\hat{h}_t} = \frac{L_t}{\hat{c}_t} \quad (1.3)$$

$$\exp(\tau_t) N_t^\eta \hat{c}_t = W_t \quad (1.4)$$

Equation (2), the first Euler equation represents the typical dynamic trade-off between consumption now and future consumption. This trade-off is a direct result from the savings decision. The second Euler equation (3) represents the new feature of our model, and it shows the trade-off between consumption of the composite final good and housing services. Finally, the third Euler equation (4) represents the trade-off between leisure and consumption.

When the households decide to own a house, their problem is to:

$$\max_{c_t, h_t, b_t, N_t} E_0 \sum_{t=0}^{\infty} (\beta)^t (\ln c_t + \alpha \ln h_t - \exp(\tau_t) \frac{N_t^{1+\eta}}{1+\eta} - \rho^i)$$

s.t.

$$\begin{aligned} c_t + Q_t h_t + b_t &= a_t \\ a_t &= W_t N_t + \Pi_t + I(owned_{t-1}) \left(\frac{I_t}{\pi_t} b_{t-1} + Q_t h_{t-1} \right) \\ \text{given } h_0, b_0 \end{aligned} \quad (1.5)$$

Solving for the first order conditions of this maximization problem we get the following Euler equations:

$$\hat{c}_t^{-1} = \beta E_t \left[\frac{I_{t+1}}{\pi_{t+1}} c_{t+1}^{-1} \right] \quad (1.6)$$

$$\frac{\alpha}{h_t} = \frac{1}{c_t} \left(Q_t - \frac{Q_{t+1}}{I_{t+1}/\pi_{t+1}} \right) \quad (1.7)$$

$$\exp(\tau_t) N_t^\eta c_t = W_t \quad (1.8)$$

Given the optimal decisions coming from both tenure choices, households will choose the one that gives him more utility. Moreover, assuming the net worth is the same and given our log utility function, the only difference between the tenure decisions is going to be the amount of housing services and consumption. Hence we have households will rent if:

$$V_{rent}^* = E_0 \sum_{t=0}^{\infty} (\beta)^t (\ln \hat{c}_t^* + \alpha \ln \hat{h}_t^*) > E_0 \sum_{t=0}^{\infty} (\beta)^t (\ln c_t^* + \alpha \ln h_t^* - \rho^i) = V_{own}^*$$

Hence, using (3) and (6) and simplifying we have that the indifferent household is given by the following equality:

$$E_0 \sum_{t=0}^{\infty} (\beta)^t L_t \hat{h}_t^{1+\alpha} = E_0 \sum_{t=0}^{\infty} (\beta)^t \left(\left(Q_t - \frac{Q_{t+1}}{I_{t+1}/\pi_{t+1}} \right) h_t^{1+\alpha} - \bar{\rho}_t \right) \quad (1.9)$$

$$\bar{\rho}_t = (1 - \beta) E_0 \sum_{t=0}^{\infty} (\beta)^t \left(\left(Q_t - \frac{Q_{t+1}}{I_{t+1}/\pi_{t+1}} \right) h_t^{1+\alpha} - L_t \hat{h}_t^{1+\alpha} \right) \quad (1.10)$$

The household that is indifferent between renting and owning pins down how many households are going to rent and own a house in equilibrium. Households that prefer to own a house at a level $\rho_i < \bar{\rho}$, will decide to own a house while households they have $\rho_i > \bar{\rho}$ will rent. Note that the cutoff rule $\bar{\rho}$ is endogenous and depends on prices and allocations.

B. Firms

The firm problem in our model is standard in the New Keynesian framework. We use a continuum of intermediate monopolistic firms together with Calvo pricing mechanism that use only labor input in production.

Each household buys their consumption good from final good firms. The final good firms buy Y_{it} from the intermediate sector for P_{it} and sell their production to the households for P_t . The technology of production of the final good firms is given by:

$$Y_t = \left(\int_0^1 Y_{it}^{1-\frac{1}{\epsilon}} dk \right)^{\frac{\epsilon}{\epsilon-1}}, \quad \epsilon > 1 \quad (1.11)$$

Individual demand for each intermediate firms product is given by:

$$Y_{it} = \left(\frac{P_{it}}{P_t} \right)^{-\epsilon} Y_t \quad (1.12)$$

Equations (11) and (12) imply that:

Intermediate firms demand labor and their production technology is given by:

$$Y_{it} = A_t N_t(k) \quad (1.13)$$

In our model nominal rigidity is imposed like in Calvo (1983) whereby a fraction of firms, $1 - \theta$, is allowed to reset price each period. The problem is symmetric and so all firms that can re-optimize choose P_t^* to solve:

$$\max_{P_t^*} E_0 \sum_{\tau=0}^{\infty} \theta^{\tau} \{ \nu_{t+\tau} (P_t^* Y_{i,t+\tau} - \Phi_{t+\tau} | Y_{t+\tau} | t) \} \quad (1.14)$$

Where $\Phi_{t+\tau}$ is the marginal cost at a specific level of production. The profits of the intermediate firms are transfers to the households. The details of the derivations of P^* in a nonlinear fashion can be found in Church (2014).

As a fraction of prices stays unchanged, the aggregate price level evolution is;

$$P_t = (\theta P_{t-1}^{1-\epsilon} + (1 - \theta) P_t^{*1-\epsilon})^{1/(1-\epsilon)} \quad (1.15)$$

If we do a first order approximation around the steady state on Equation (15) together with the solution to (14), we get the forward-looking Phillips curve. In our case, we will do a second order approximation because agents use welfare when deciding to own or rent. Hence, we a second order approximation around steady state in order to have an accurate

solution of the model.

C. Consumer Price Index

With the explicit introduction of housing rents, we can formalize the implied consumer price index in our model economy. The consumer price index is going to be a weighted average of nominal prices of housing and non-housing goods. We assume the weight a of 0.3 on housing shelter that is the same as in the data CPI. Hence we have CPI inflation is given by:

$$CPI_t = a \frac{P_t}{P_{t-1}} + (1 - a) \frac{P_t}{P_{t-1}} \frac{L_t}{L_{t-1}} \quad (1.16)$$

The consumption good real price is 1 and hence the price variation is given by monetary inflation. However, housing rents nominal change of prices is a composition of monetary inflation and real housing rents inflation. From equation (16) it is clear that CPI gives a guidance on how monetary inflation behaves in trend if real prices behave like some white noise. However, if real prices change strongly and persistently in opposite directions, CPI becomes noisy as a measure of monetary inflation. This model provides a formal way to start thinking about how monetary inflation should be measured, and goes in the direction of providing insights to the points raised in Vining and Elwertowski (1976).

D. Central Bank

The central bank implements a Taylor-type of interest rate rule. Hence, central bank reacts to output gap and inflation gap according to:

$$I_t = (I_{t-1})^{\phi_I} (CPI_{t-1}^{1+\phi_\pi} (Y_{t-1}/Y)^{\phi_Y} r)^{1-\phi_I} e_{I,t} \quad (1.17)$$

We assume all agents in the economy measure well monetary inflation and know the central bank targets the implied CPI with housing rents. In the counterfactual section we show how this economy differs from one where the central bank reacts to a CPI that is rents-free.

E. *Exogenous Shocks*

In our model economy τ_t has follows an AR(1) process:

$$\tau_t = \rho_\tau \tau_{t-1} + e_{\tau,t} \quad (1.18)$$

Hence, there are two kinds of shocks: a preference on leisure shock $e_{\tau,t}$ and a monetary policy shock $e_{I,t}$. Both shocks follow a normal distribution $e_{\tau,t} \sim N(0, \sigma_\tau)$ and $e_{I,t} \sim N(0, \sigma_I)$, respectively.

F. *Market Clearing*

The market clearing conditions in our economy are the following:

Goods Market

$$\gamma \int_0^{\bar{\rho}_{t-1}} c_t di + (1 - \gamma) \int_0^{\bar{\rho}_t} c_t di + \gamma \int_{\bar{\rho}_{t-1}}^1 \hat{c}_t di + (1 - \gamma) \int_{\bar{\rho}_t}^1 \hat{c}_t di = W_t + \Pi_t \quad \forall t \quad (1.19)$$

Labor Market

$$\int_0^1 N_{jt} dj = N_t \quad \forall t \quad (1.20)$$

Homeowners housing market

$$\gamma \int_0^{\bar{\rho}_{t-1}} h_t di + (1 - \gamma) \int_0^{\bar{\rho}_t} h_t di = H^O \quad \forall t \quad (1.21)$$

Rental housing market

$$\gamma \int_{\bar{\rho}_{t-1}}^1 \hat{h}_t di + (1 - \gamma) \int_{\bar{\rho}_t}^1 \hat{h}_t di = H^R \quad \forall t \quad (1.22)$$

Nominal Bonds Market

$$\gamma \int_0^{\bar{\rho}_{t-1}} b_t di + (1 - \gamma) \int_0^{\bar{\rho}_t} b_t di + \gamma \int_{\bar{\rho}_{t-1}}^1 \hat{b}_t di + (1 - \gamma) \int_{\bar{\rho}_t}^1 \hat{b}_t di = 0 \quad \forall t \quad (1.23)$$

G. Equilibrium

Definition. *The Rational Expectations Competitive Equilibrium is a sequence household choices $\{c_t, \hat{c}_t, h_t, \hat{h}_t, b_{t+1}, \hat{b}_{t+1}, N_t\}_{t=0}^\infty$, a sequence of housing tenure choice (rent vs own) $\{o^i\}_{t=0}^\infty$, profits and transfers $\{\Pi_t\}_{t=0}^\infty$, a cut-off preference level that makes the households indifferent between renting and owning $\{\bar{\rho}_t\}_{t=0}^\infty$ and a sequence of prices $\{W_t, Q_t, L_t, P_t, P_t^* CPI_t, I_t\}_{t=0}^\infty$ such that:*

- 1) *Given prices and profits, $\{c_t, h_t, b_{t+1}, N_t\}_{t=0}^\infty$ solves the households problem when owning and $\{\hat{c}_t, \hat{h}_t, \hat{b}_{t+1}, N_t\}_{t=0}^\infty$ solves the households problem when renting.*
- 2) *Given prices and allocations, $\{\bar{\rho}_t\}_{t=0}^\infty$ solves equation (10).*
- 3) *Given prices and allocations, $\{P_t^*\}_{t=0}^\infty$ solves (10) and profits $\{\Pi_t\}_{t=0}^\infty$ are the associated indirect function (14) with optimal price $\{P_t^*\}_{t=0}^\infty$.*
- 4) *Given allocations, $\{W_t, Q_t, L_t\}_{t=0}^\infty$ solve market clearing (19), (20), (21), (22) and (23).*
- 5) *Given prices and allocations, $\{P_t\}_{t=0}^\infty$ solves equation (15), $\{CPI_t\}_{t=0}^\infty$ solves equation (16) and $\{I_t\}_{t=0}^\infty$ solves equation (17).*

1.4 Calibration and Solution

We calibrate the model to match long-term moments of the US economy. All parameter values are taken from previous literature on New Keynesian models like Iacoviello (2005), Clarida et al. (1999) and Christiano et al. (2005). In Table 1 we show the parameters values. The inter-temporal discount factor was selected to match the US steady state annual interest rate approximately.

Description	Parameter	Value
<i>Preferences</i>		
Discount Factor	β	0.99
Weight on housing services	α	0.10
Labor Supply Aversion	η	0.01
<i>Tenure Choice</i>		
Friction	$1 - \gamma$	0.0375
<i>Sticky Prices</i>		
Steady State Markup	X	1.20
Probability of fixed price	θ	0.75
<i>CPI</i>		
Housing Rents Share in CPI	a	0.30
<i>Taylor Rule</i>		
Interest Rate Smoothing	ϕ_I	0.80
Reaction to Inflation Gap	ϕ_π	1.50
Reaction to Output Gap	ϕ_Y	0.10
<i>Exogenous Shocks</i>		
Persistence of Leisure Preference Shock	ρ_τ	0.90
Leisure Preference Shock Std. Dev.	σ_τ	0.010
Interest Rate Shock Std. Dev.	σ_I	0.007

Table 1.1: Benchmark model calibrated parameters. The γ parameter is calibrated to match that 15% of households move in given year (Bachmann and Cooper (2014)). All other parameters are selected from previous literature on standard New Keynesian models like Clarida et al. (1999), Christiano et al. (2005), and Iacoviello (2005).

The parameter that governs the labor supply aversion with a value of 0.01 implies a practically flat labor supply. This is higher than what microeconomic studies suggest, but it is consistent with the weak observed response of real wages to macroeconomic disturbances and moreover can be motivated by the changes in labor supply coming from the extensive margin. That is the amount of individuals that change from unemployed to employed, even though hours works do not change much for individuals at work.

The preference parameter on housing services is justified by Iacoviello (2005). Our preferences are the same the exception that we do not model explicitly money. However, money has a insignificant impact on utility function in Iacoviello (2005), which is typically the case in money in the utility models. The markup is taken from Christiano et al. (2005). The housing rents share in CPI is around 30%. The Taylor rule parameters are taken from Clarida et al. (1999) and are similar to those used by Iacoviello (2005). These parameters imply a Taylor rule that describes well monetary policy post Volcker period. Finally, the shock on monetary policy was calibrated to match the initial response of interest rates of the benchmark SVAR.

The model is solved using a perturbation method with a second order approximation around the steady state. The second order approximation in our model is crucial because agents compare lifetime utility function when deciding on whether to own or rent a house. It is well known that first order approximations give inaccurate solutions to welfare analysis because they miss second moments. Hence, with the second order approximation and small shocks we are able to accurately solve the model.

Although our model is highly stylised, Table 2 shows the model performs remarkably well in matching long term moments like ownership rate and price to rent ratio, as well as business cycle moments. Although the source of heterogeneity in our model comes only from preferences, and that the housing supply side is introduced in a very simple way, the homeownership rate we get from our model is close to the data. Our preferences heterogeneity is, in some sense, a reduce form approach to what drives the homeownership rate. For the fundamentals behind the homeownership rate and the price to rent ratio see Chambers et al. (2009), Sommer et al. (2013) and Miao et al. (2014). Moreover, the price to rent ratio is also similar to the average price to rent ratio found in the data, which suggest supply dynamics do not seem to be important in matching long term housing tenure choices dynamics.

Besides housing prices standard deviation , the model business cycles standard deviation matches well the data. The model predicts housing prices that almost doubles that of the data. One reason can be the missing housing market fundamentals in the model and another reason might be the lack of stickiness in housing rents. Housing rents are very sticky in reality and in our model they are assume flexible. Given how our mechanism for homeownership

Moments	Model	Data
<i>Steady State</i>		
Homeownership rate	0.70	0.64
Price-Rent Ratio	23.29	18.80
<i>Business Cycle</i>		
CPI Std. Dev.	0.025	0.015
Output Std. Dev.	0.099	0.014
Housing Prices Std. Dev.	0.103	0.054
Housing Rents Std. Dev.	0.0083	0.0069

Table 1.2: Model *versus* Data comparison of moments that were not targeted

works, if rents do not respond as strongly specially when decreasing (housing rents stickiness is not symmetric), housing prices will not change as abruptly and this will dampen housing prices volatility.

With the model calibrated we show the theoretical impulse-response functions in Figure 1.6. The tenure choice mechanism enables the New Keynesian model to opposite responses of housing prices and housing rents in response to a monetary monetary contractionary shock. Housing prices decrease and housing rents increase after nominal interest rates increase. This result is puzzling if one thinks of housing as an asset only. However, housing is also a consumption good and utility considerations are hence important in determining prices. If houses are just assets, one would expect housing prices are nothing but the present value of all future housing rents. Hence, changes in interest rates would have to change both housing prices and rents in the same direction. However, housing is not just an asset and households buy housing stock not just to rent it but also to consume it. Hence, there is a dichotomy between rents and housing prices.

Moreover, with heterogeneous agents, households have different valuations for the same housing stock. When interest rate increase, more agents prefer to rent instead of owning creating a change in housing demand in the extensive margin. We can see in Figure 1.6 that indeed this is the case looking at how homeownership rate decreases after interest rates rise.

The consideration of housing rents allows us to introduce a theoretical consumer price

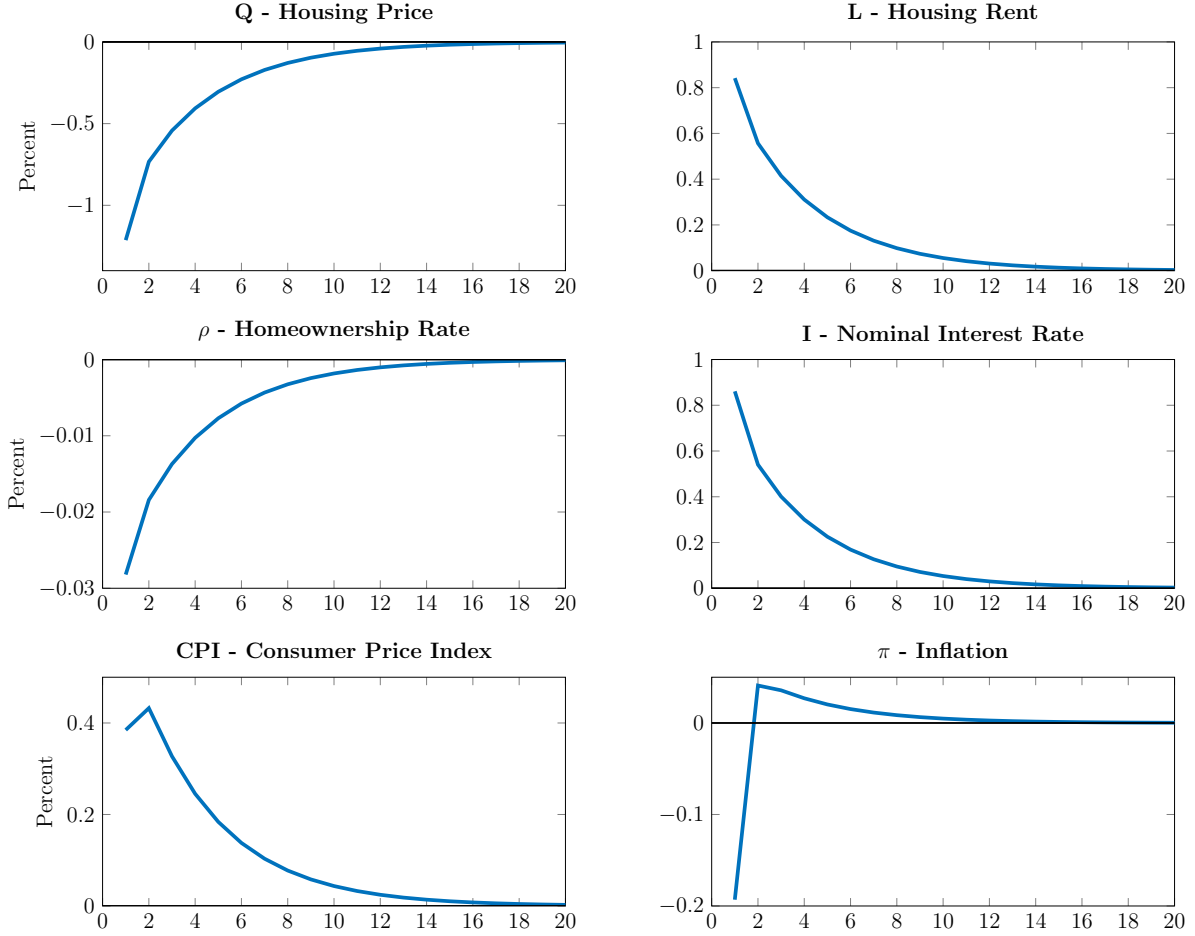


Figure 1.6: Impulse-Response functions for main variables of interest for the benchmark model where the Taylor rule targets CPI. Each graph shows percentage points response of one of the model's variables to a one standard deviation shock in monetary policy.

index. We can see in Figure 1.6 that CPI increases in spite of the fact monetary inflation decreases. This is the result of rising rents that is sufficiently large to overcome the drop in monetary inflation. CPI then decreases since housing rents start decreasing. Interestingly, when CPI is targeted by the Taylor rule, monetary inflation first decreases and then increases above steady state. Since, the monetary authority overshoots interest rates households cut consumption sharply. As a response to the drop in demand, firms first cut down employment and decrease prices to maintain the fixed markup. However, households and firms know the monetary authority is targeting CPI, and once CPI behaves normally, they know the interest rates are going to quickly drop making them increase consumption. Firms again increase employment and prices increase given the higher wages. The employment and

output responses can be found in the appendix A in Figure A.1.

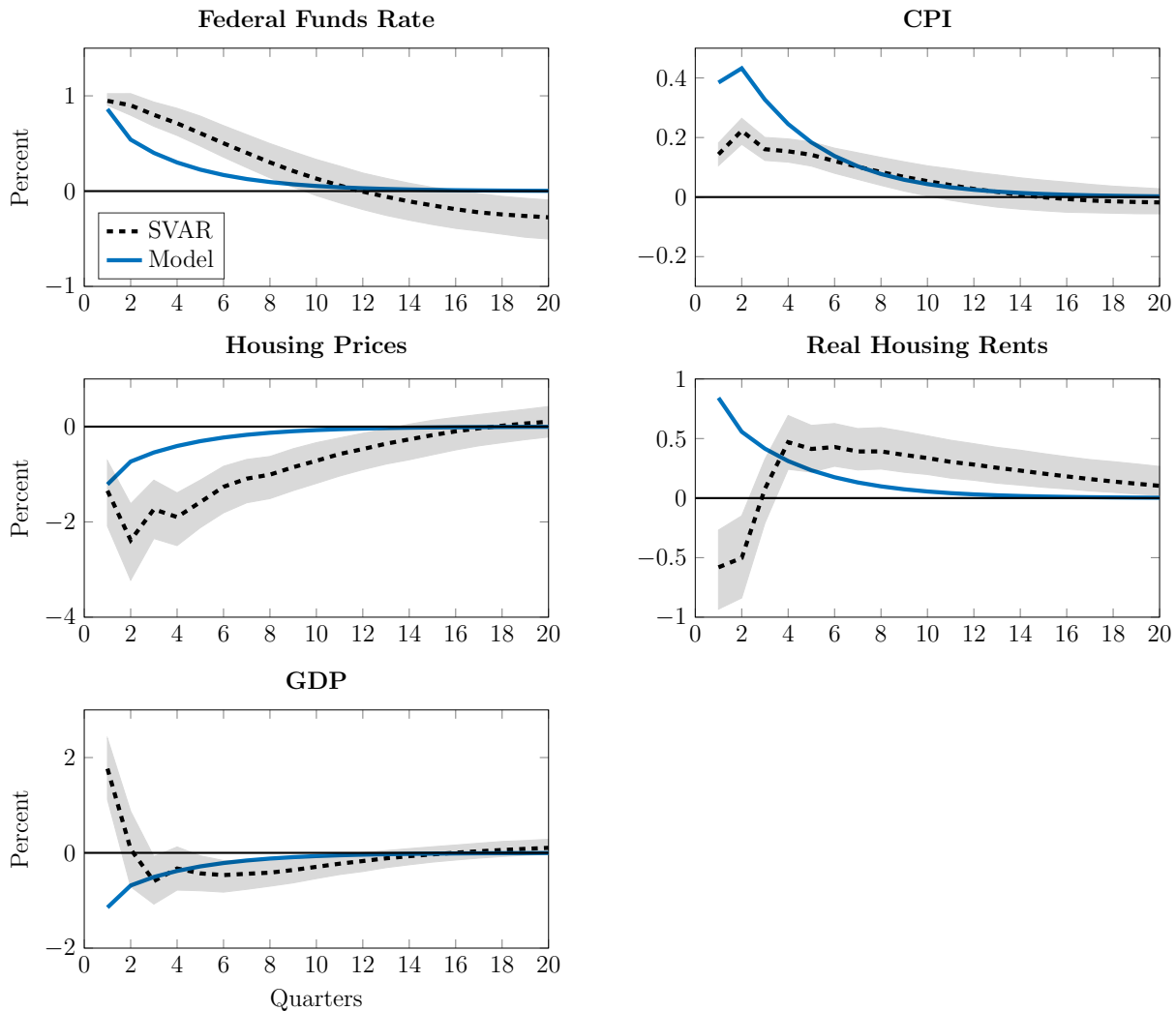


Figure 1.7: Impulse-Response functions for main variables of interest for the benchmark model where the Taylor rule targets CPI *versus* SVAR with Choleski identification that is consistent with the model. Each graph shows percentage points response of one of the model's variables to a one standard deviation shock in monetary policy.

Looking at Figure 1.7, we can see that the model impulse responses matches well the SVAR impulse response functions. Housing rents increase while housing prices and output fall. Moreover, we are able to match the “price puzzle” that commonly appears in the SVAR literature on monetary policy. Hence, looking at a theoretical measure that allows to construct a price index similar to a CPI, there is no puzzle in a rising CPI while nominal inflation is decreasing. This happens because the rise in housing rents out weights the

decrease in nominal inflation. We explore this insight in Chapter 2 and show that the price puzzle is largely explained by housing rents. Our results suggest a mechanism that can generate the price puzzle different from the so called channel cost of monetary policy (Barth and Ramey (2001)) and Christiano et al. (2005). To test this hypothesis, Rabanal (2006) estimates a New Keynesian model of the business cycle and tests the conditions under which a cost channel of monetary policy could generate a positive response of prices to a contractionary monetary policy shock. This author finds that, demand side effects always dominate supply side effects in prices and therefore there is no evidence that the cost channel of monetary policy could explain the price puzzle. Our results provide some insights on the type of demand shocks that drive the response of prices.

The fit is particularly not good in the first periods. This is mainly due to the identification assumption of the SVAR. We are faced with a trade-off, we either make an identification ordering that is consistent with the timing assumptions of the model, or we get a better identification. This trade-off was also faced by Iacoviello (2005). We decided to follow Iacoviello (2005) and opted for the former one by sacrificing some identification to make the SVAR more consistent with the model. Hence, given that in the model all variables respond contemporaneously to shocks in interest rates, we order the federal funds rate first in the SVAR. Besides, the initial periods, the economy behaves similarly to the SVAR. Finally, it is worth noting that rents are flexible in the model while in reality rents are very sticky as shown by the SVAR response of housing rents. If our model had rents being stick like the data, our theoretical CPI would be able to be always positive like in the data. For more details on the price puzzle see Chapter 2.

1.5 Counterfactual - CPI *versus* CPI net of rents

Here, we ask the question on how the dynamics of the model in the benchmark case compare to the alternative setting, where the monetary authority targets a rents-free consumer price index. Note that the rents-free price index is just the usual monetary inflation studied in most of the standard New Keynesian models.

We show in Figure 1.8 the impulse responses of the two different cases. In the alternative

case, where the monetary authority targets the rents-free CPI, interest rates will be lower than in the benchmark as a response to the same shock. This happens because when the monetary authority targets the consumer price index with housing rents, CPI will be initially above the target, and hence interest rates will be set too high to bring CPI to the target⁸. The increase in CPI is in turn driven by rising housing rents. Although the differences are small in a response to a single shock, these differences can become rather large when accumulating different shocks to the economy over time. Moreover, if rents were sticky, CPI distortions would be much larger in later periods. Real interest rate is similar with the exception of the first period.

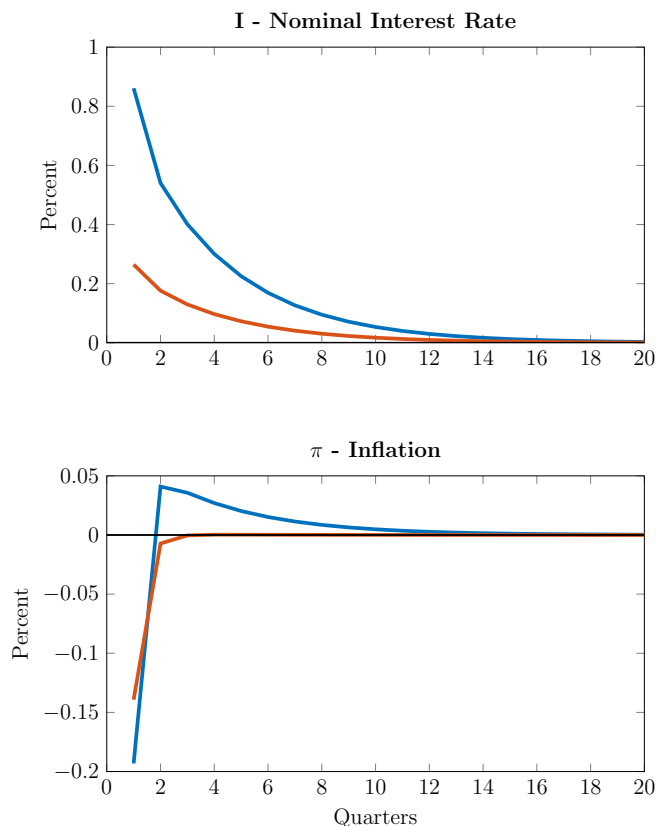


Figure 1.8: Impulse-Response functions for main variables of interest for the benchmark model where the Taylor rule targets CPI (blue) *versus* alternative setting when Taylor rule targets nominal inflation π (red). Each graph shows percentage-point response of one of the model's variables to a one standard deviation shock in monetary policy.

⁸We also perform a counterfactual for the PCE, and a composite CPI that takes into account homeownership costs for the homeowner as well as rents. The results can be found in Figure A.3 in the appendix A.1.

When interest rate Taylor rules use the CPI as an input, interest rates will be set too high based on rising rents instead of nominal inflation and will add unnecessary variation to the underlying inflation rate. This generates large welfare costs and losses to a monetary policy whose objective is to minimize inflation and output gap variance. Table 3 reports the welfare analysis. We simulate the model with monetary policy shocks for one thousand periods. We find that targeting a measure of inflation that excludes housing rents leads to a 0.9% welfare gain in consumption equivalent variation and to a 14.5% fall in the loss function of monetary policy in comparison to the case that the monetary authority targets a measure of inflation that includes housing rents. Households are affected differently. Owners are affected more in consumption equivalent variation because housing prices are more volatile to interest rate shocks than housing rents.

	Benchmark Model (Target CPI)	Alternative Model (Target π)	$\Delta\%$
<i>Welfare</i>			
<i>Utility</i>	0.2610	0.2703	+3.56%
<i>Owner</i>	0.4920	0.5010	+1.84%
<i>Renter</i>	-0.1462	-0.1379	+5.65%
<i>Consumption Equivalent Variation</i>	1.3563	1.3690	+0.93%
<i>Owner</i>	1.6355	1.6504	+0.91%
<i>Renter</i>	0.8640	0.8712	+0.83%
<i>Monetary Policy Loss Function</i>	0.063	0.054	-14.55%

Table 1.3: Welfare Analysis and Monetary Policy Function. All the numbers reported are the result of simulating the model for 1000 periods, with the initial value set at the steady state. The monetary policy function is the quadratic function $\sum_{t=0}^{\infty} \beta^t (\pi_t^2 + \lambda(y_t - y_{tn}))$ computed with $\lambda = 0.003$.

Finally, using the same counterfactual, we answer how prices dynamics might have been different for the U.S. experience between 1984 and 2006. With two shocks, we assume that only housing prices and CPI are observable. Then, using the Kalman filter with the calibrated parameters we are able to recover the monetary policy and preference shocks for the

1984-2006 by matching observed series of housing prices and CPI for the same time period. Figure 1.9 shows the graphs for housing prices and CPI. We can see that the benchmark model replicates the dynamics of housing prices quite well. We then simulate the model with the same shocks and show how the price dynamics would differ if the monetary authority reacted to a rents-free consumer price index. First, we find that under the alternative scenario, the standard deviation of housing prices would have been 24.8% lower for the 1984-2006 US experience. Secondly, we estimate that this mechanism can explain 37.5% of the increase in house prices above trend from 2002 to 2006.

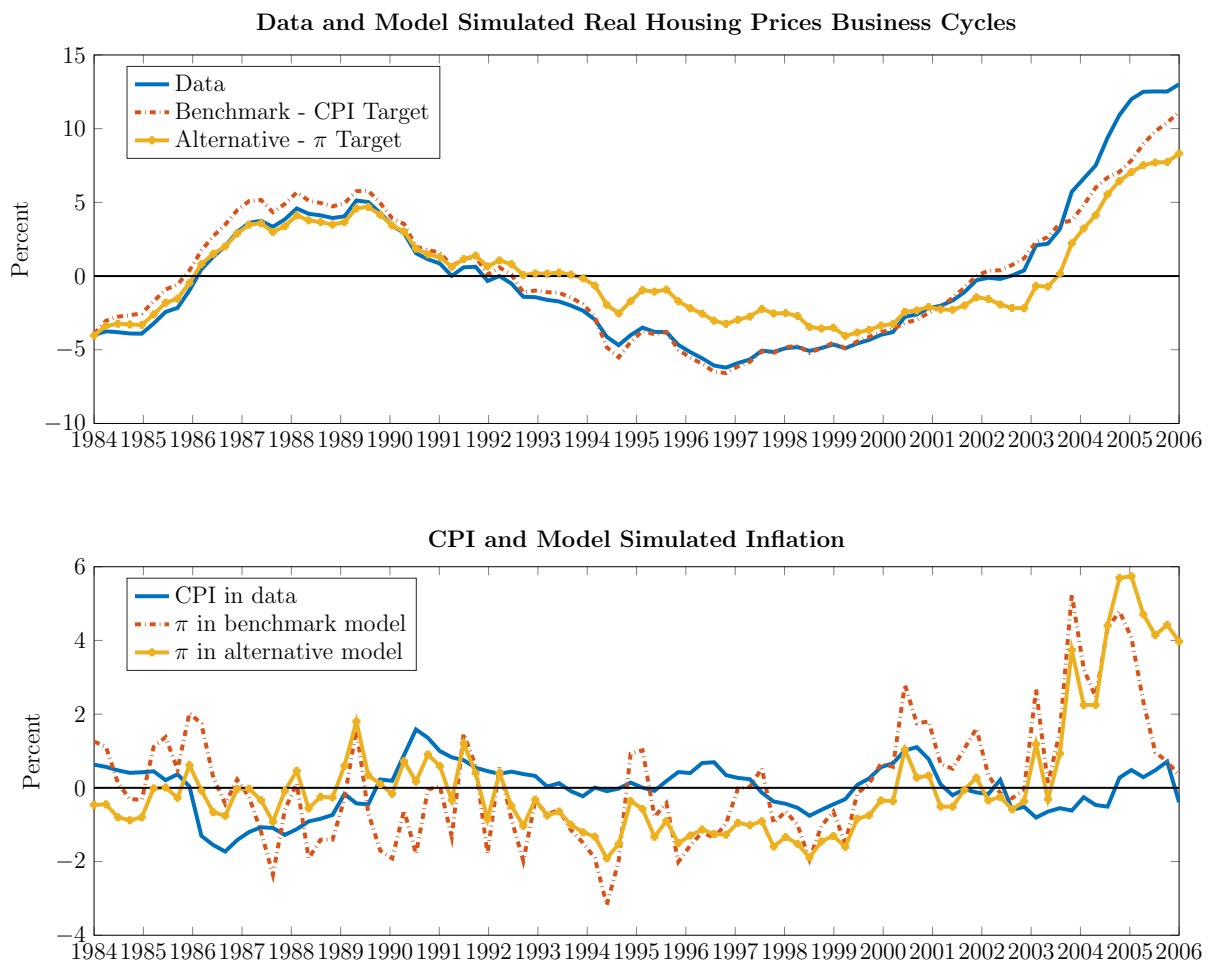


Figure 1.9: Housing Prices Business cycle on top and CPI business cycle for data from 1984 to 2006 with simulated data from the benchmark and simulated model. All business cycles are computed using a HP filter. In the model, by assuming we only observe housing prices and CPI we extract the implied monetary policy and preference shocks using Kalman Filter. We use the recovered shocks to simulate the model.

From the second graph in Figure 1.9 we observe that CPI gives indeed a poor estimate of monetary inflation. Moreover, this mismeasurement is dynamic and changes over time depending on how housing rents behave. When the monetary authority increases (decreases) interest rates, *real* housing rents increase (decrease). This creates a measurement issue in tracking underlying nominal inflation and leads to a downward (upward) estimate of inflation when CPI are used. Because directly and indirectly, housing rents have a fairly large weight on CPI, this mismeasurement may be sufficiently large and lead the monetary policy authority to keep setting interest rates too high (low) in its attempt to achieve a certain inflation target.

It is worth noting that the monetary authority has been targeting PCE instead of CPI. However, the weight on housing rents is still large, and is particularly high when looking at core PCE. The hazardous effects of the mismeasurement would be smaller than in the CPI and hence one can think of the CPI as an upper bound to the implications on monetary inflation. Next, when we compare the benchmark with the alternative scenario, we find that the standard deviation of nominal inflation would have been 19.9% lower. In the alternative case, the CPI seems to track better monetary inflation than in the benchmark case. Finally, it is interesting to note how nominal inflation looked uncontrolled before the recent financial crisis. This might be the result of apparently low inflation measures through CPI because of falling housing rents. When the CPI increases, the benchmark monetary inflation quickly comes back to target while the alternative monetary inflation falls but not as much. This might be explained by the low reaction of interest rates to shocks in the alternative model. We do also see a drop in monetary inflation, but not as big as in the benchmark case. This smaller drop can be explained by the fact that the shocks are identified observing CPI using the benchmark case.

1.6 Conclusion

In this paper we unveil a new channel through which housing reveals its importance in the economy by investigating the interaction between monetary policy and housing rents. Using

SVARs and FAVARs, we first show housing rents respond positively to a contractionary monetary policy shock. Secondly, recognizing housing rents directly and indirectly account for about 30% of CPI, we show our first finding brings new insights on inflation measurement and strong implications to the way monetary policy is conducted. We propose and calibrate a DSGE model that endogeneizes housing tenure choice and is both able to explain the empirical findings and provide answers for monetary policy experiments.

Counterfactual exercises reveal that when the Taylor rule uses the CPI as an input, interest rates will be set too high based on rising rents instead of currency inflation. This generates large welfare costs, adds unnecessary variation to the underlying monetary inflation rate and losses to a monetary policy whose objective is to minimize inflation and output gap variance. Finally, by simulating the model we find monetary policy based on CPI explains a large proportion of the housing price business cycle boom that preceded the 2008 financial crisis.

We do not make the case for the exclusion of housing rents from the consumer price indexes in every circumstance. Housing rents are an important item on measuring households cost of living since households spend around 30% of their income with shelter, and hence should be included. In general, price indexes trends capture well the evolution of the nominal state of the economy. However, when relative prices of some specific goods change suddenly, the consumer prices indexes are affected regardless of how underlying monetary inflation behaves. Given that we show housing rents relative price is strongly affected by monetary policy and that housing rents have a large weight in the consumer price indexes, care should be in place when interpreting the response of consumer price indexes to monetary policy shocks as purely monetary inflation.

CHAPTER 2

THE EFFECT OF MONETARY POLICY ON HOUSING TENURE CHOICE AS AN EXPLANATION FOR THE PRICE PUZZLE

2.1 Introduction

Using structural vector autoregression (SVAR) analysis, Sims (1992) noted that inflation responded positively and persistently to a contractionary monetary policy shock. This result is puzzling because a central tenet of monetary policy is the ability to control prices by contracting or expanding monetary supply (*vis-a-vis* increasing or decreasing interest rates) when prices are above or below the desired level, respectively. Since this result was first found, and starting with the paper where it was first shown (Sims (1992)), several explanations have been proposed. In this paper, we contribute to this literature by proposing an alternative explanation of the price puzzle based on the effects of monetary policy on housing tenure choice and the weight of shelter in the overall consumer price index (CPI).

In Chapter 1 we show that, in response to an expansionary monetary policy shock, house rents decrease while house prices increase. We use the effects of monetary policy on housing tenure choice decisions together with heterogeneous valuation of homeownership by agents to explain this result. When interest rates change, the marginal home buyer may change, which may make house and rent prices change. Because with a higher interest rate the cost of homeownership may increase, more people may prefer to rent instead of buying. This shift in consumption behavior makes house prices decrease and rents increase. This mechanism, together with the fact that shelter, directly and indirectly, accounts for about 30% of the overall CPI, can help explain the price puzzle. When interest rates increase (a contractionary monetary policy shock), the nominal price level decreases, but rents will increase if the share

Joint work with Daniel A. Dias.

of buyers declines and the share of renters increases. If the increase of rents is sufficiently larger than the decrease of the nominal price level, then it can be expected that, after a contractionary monetary policy shock, inflation, measured by CPI, will increase. We test this idea using structural vector autoregression analysis, similar Sims (1992). Our empirical results strongly support our idea, and when we take into account the effect of monetary policy on rents and the weight of shelter in CPI, we find that after a contractionary monetary policy shock, the price puzzle is substantially reduced or even disappears. Our results are robust to alternative shocks identification strategies, measures of the price level, sample periods, and identification strategies. Exogenous changes in the construction of CPI allowed us to test our theory further. In addition, using different measures of inflation, like the personal consumption expenditure (PCE) and the deflator of gross domestic product (GDP), in which the weight of shelter/housing is lower than in the CPI, permitted us to conduct additional robustness check exercises.

As already mentioned, Sims (1992) proposes the first solution to the price puzzle. The author argues that the puzzle is due to model misspecification and that, when a commodity price index variable is included in the SVAR model, most of the puzzle disappears. Hanson (2004) shows that this solution is sensitive to the sample period. In particular, the inclusion of commodity prices solves the puzzle for sample periods before 1980 but not for posterior sample periods. In line with the explanation of Sims (1992), several other papers justify the puzzle with model misspecification. Giordani (2004) argues that the price puzzle is mostly a spurious result due to not including a measure of the output gap in the empirical model. Once this variable is included in the SVAR model, the effect of a contractionary monetary policy shock on prices is still positive in the first periods but then becomes negative. Bernanke et al. (2005) also argue that the SVAR model used by Sims (1992) was misspecified and suggest the utilization of a factor augmented vector autoregressive (FAVAR) model to correct for the misspecification. Using the suggested model, the authors obtain a response of inflation to a contractionary monetary policy shock that is closer to the expected response. Brissimis and Magginas (2006) also argue that the model used by Sims (1992) is misspecified and the source of misspecification is the lack of forward-looking variables to account for expectations at the time of the change of interest rates. To fix this problem, the authors added the fed

funds futures rates and a composite leading indicator of economic activity to the empirical model. With the new specification, these authors obtain a response of inflation to monetary shocks that is much more in line with what would be expected.

An alternative line of research that also aims to explain the price puzzle tries to produce theoretical models in which prices increase after a contractionary monetary policy shock. One theory that could deliver such a result is the so-called channel cost of monetary policy (Barth and Ramey (2001)). To test this hypothesis, Rabanal (2006) estimates a New Keynesian model of the business cycle and tests the conditions under which a cost channel of monetary policy could generate a positive response of prices to a contractionary monetary policy shock. This author finds that demand side effects always dominate supply-side effects in prices and, therefore, there is no evidence that the cost channel of monetary policy can explain the price puzzle. Our results provide some insights on the type of demand shocks that drive the response of prices. In contrast to Rabanal (2006), Henzel et al. (2009) estimate a New Keynesian DSGE model for the euro area and argue that, under certain parameter restrictions, which are not rejected by the data, the channel cost of monetary policy can explain the price puzzle.

Our contribution combines both types of explanations and adds to them. We also find that the SVAR model in Sims (1992) is misspecified, and suggest a way to improve the specification of the model. In addition, we provide a theoretical explanation (the effect of monetary policy on housing tenure choice) for why (some) prices may increase after a contractionary monetary policy shock.

The rest of the paper is organized as follows: in section 2.2 we discuss some practical issues regarding the calculation of the CPI; in section 2.3 we present a simple conceptual framework to guide our empirical implementation; in section 2.4 we describe our data and data sources; in section 2.5 we present our main empirical results; in section 2.6 we perform several robustness checks; in section 2.7 we compare our explanation of the price puzzle to other explanations; and in section 8 we conclude.

2.2 Housing in the CPI

In this section we present some information regarding the construction of the CPI and discuss how some of the methodologies used in the construction of the CPI can help in understanding the price puzzle. The first aspect about the CPI that we note is that total housing expenses have a 46% weight in the index. This component has two sub-components, shelter and other housing related expenses, with the former currently weighing 31% in total CPI and the latter 15%.¹ This information suggests that the overall CPI may be very sensitive to what happens in the housing component given how large its weight is.

A second aspect to note is that, although the price of most of the sub-components of housing (e.g., utilities or insurance) are relatively easy to measure, the price of shelter is not. The price of shelter is easy to measure when someone lives in a house that does not belong to her, but very hard to measure in the case of someone living in a house that belongs to her. When someone lives in her own house, there is no established price for the rent that this person would have to pay if she was renting that same house. Over time, there have been different methods to address this problem, and these different methods can attenuate or exacerbate the price puzzle.

Before February 1983, the CPI calculated shelter costs differently than what is done today.² The cost of housing shelter for homeowners was based on housing prices, mortgage interest rates, property taxes, insurance, and maintenance costs. Hence, it included the asset as well as the service characteristics of housing when estimating the costs of shelter for homeowners. Some problems with the methodology and with the technical measurement itself were pointed out by the Bureau of Labor and Statistics (BLS) and the research community. The main concerns raised were the following: the difficulty faced by the BLS in correctly estimating the mortgage interest rate cost because of the new financial contracts involving variable interest rates and specific special arrangements; the difficulty in estimating housing prices

¹In this paper, shelter costs only corresponds to rents and the owners' equivalent rent. The shelter sub-component of CPI also includes other items which are not relevant to the discussion of the paper. These other items only weigh 1.1% in total CPI. Hence, total shelter is around 31% and rent plus owners' equivalent rent is almost 30%.

²For a more detailed discussion about the changes in the CPI methodology, please see Gillingham and Lane (1982) and the BLS document on CPI methodology, "How the CPI measures price change of Owner's equivalent rent of primary residence (OER) and Rent of primary residence (Rent). "

given the small sample and the low frequency with which houses are traded; the general concern of the BLS that CPI should have a strong credibility and the possibility that the way housing shelter was being estimated together with its importance in the CPI could be negatively affecting the credibility of the index; and lastly, the idea that CPI should be as close as possible as a good measure of consumption expenditure and, hence, homeownership costs should be computed as closely as possible to a consumption good and not to an asset.

Given the dissatisfaction with how the cost of shelter for homeowners was computed and the necessity for a more purely consumption-oriented index, the BLS suggested an alternative measure called owner's equivalent rent (OER) of primary residence. The idea behind this new measure was to ask how much rent would the homeowner have to pay if she had to rent her own house. In order to answer this question, the BLS defined small geographic areas, called segments, within each of the 87 CPI pricing areas. A segment corresponds to one or more Census blocks. For each segment, the BLS collects prices from the rental market of houses that are representative of that segment. This approach allows the BLS to get an implicit rent for owners by comparing houses that have similar characteristics as the representative ones in the rental market in the same segment. In other words, the BLS uses hedonic pricing methods to estimate the OER. Hence, the OER is very closely related to the rental prices observed – the correlation between the level of rental prices and OER is 0.996 while the correlation between the year-on-year growth rates is 0.842. Therefore, the OER can essentially be seen as a measure of shelter costs faced by homeowners that is based almost solely on the price of rents from the rental market. The CPI based on this new measure was first introduced in February 1983, and during a period of six months, until July 1983, the CPI was calculated using the two measures of shelter costs. This change in methodology allows us to compare the size of the price puzzle when two alternative measures of shelter costs are used in the construction of the CPI. In our baseline empirical estimation we consider a sample starting in January 1983 and ending in December 2006.³

Finally, we present how the relative importance of housing total rent (rent of primary

³We truncate the sample at the end of 2006 to avoid the financial crisis period because during this period, there were several shocks affecting the usual monetary transmission mechanism, which could affect our analysis for reasons beyond the scope of this paper.

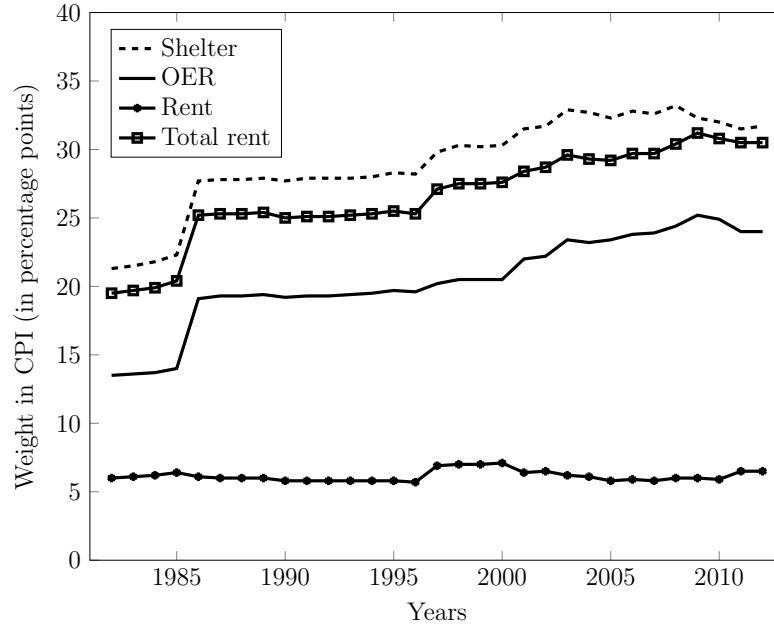


Figure 2.1: Weight of rent, owners' equivalent rent, and total shelter costs in CPI between 1982 and 2012.

Source: BLS.

residency plus the owners' equivalent rent) evolved between 1982 and 2006. Figure 2.1 shows the evolution of selected items' weights in CPI. It is clear that almost all of the increase in the relative importance in CPI of housing rents is driven by the OER. The initial increase in the OER share in the CPI from 13.5% to 19% was driven by a re-weight in 1981-82. The initial weight of 13.5% was based on 1971-72 expenditure information. This lag in the re-weighting process of the CPI created a data blip in the OER. After 2000, when the weight started being estimated every two years, this lag problem was reduced. However, for the OER, the revision took place in 1982 and, at the time, the weights were still given by the 1971-72 period, which explains the large increase of the shelter weight in the first years of the OER implementation. The increase of the share of the OER did not restrict itself to the beginning of the 1980s. After that, the OER share increased from 19% to 24% in 2012. The change in 2012 was mostly due to an increase in the quantity demanded of OER.⁴ At the same time, the share of rents did not change much. There were some small

⁴For details, see Church (2014).

variations, but overall the share of rents remained fairly stable. One possible explanation is that the housing sizes for rental units did not increase as much as the size of the houses that are owned by its occupants. Also, there was a large increase of homeownership, especially during the 2000-2006 period. This fact seems relevant in explaining the slight decrease of the weight of rent and the increase of the weight of OER in the overall CPI in this period.

Before proceeding to the discussion of the conceptual framework, an important remark is in place. Although all the previous discussion was only about the construction of the CPI, similar problems are faced by other alternative measures of inflation such as the the PCE and the deflator of GDP. The problem of estimating the price of shelter is also present in these two indexes, but it is less important for explaining the price puzzle because the weight of shelter is significantly lower than in the CPI (15% in the PCE and 13% in the deflator of GDP).

2.3 The effect of interest rates on the nominal state of the economy and the CPI

It is well known that the CPI as a measure of monetary inflation has several problems for the conduct of monetary policy. One of these problems is that the CPI is not able to separate price changes caused by changes in the nominal state of the economy from price changes caused by supply and/or demand shocks (relative price changes). The usual way to solve this problem is to construct measures of core inflation. These can be as simple as removing the more volatile components of CPI like energy and unprocessed food, or they can be more elaborate and come out of econometric models (see Clark (2001) for a survey of core inflation measures). The measurement issue that we point out in this paper adds to the list of problems with using CPI (or other measures like the PCE or the deflator of GDP) as a measure of monetary inflation, but it has important differences from the other problems previously identified because, according to our idea, the relative price change is due to changes in interest rates *vis-a-vis* monetary policy. In order to make our point clearer,

we write the CPI as the product of two components.

$$CPI(t) = P(t)(\alpha C(t) + (1 - \alpha)R(t)) \quad (2.1)$$

The first component in equation 2.1 corresponds to the nominal state of the economy at time t – $P(t)$ – while the second component corresponds to the real prices of non shelter and shelter consumption – $(\alpha C(t) + (1 - \alpha)R(t))$. In this example we only consider two goods/services, consumption net of shelter – $C(t)$ – and shelter – $R(t)$ – because we want to focus our discussion on the different behavior of the two groups of goods/services in response to a monetary shock. In the same equation, α represents the weight of non-shelter consumption in total consumption.

In Chapter 1 we argue that monetary policy affects the choice between housing tenure (rent vs. own) and therefore the relative prices of the two change when interest rates change. From our discussion in the previous section, for the purpose of computing the costs of shelter, most of the information used in these calculations comes from the shelter rental market, which leads to the shelter component of CPI behaving almost identically to shelter rents. With this in mind, and with equation 2.1, we can now discuss when we expect to observe a price puzzle based on our mechanism.

When the central bank increases interest rates it is normally for the purpose of reducing inflation, that is, to reduce the growth rate of $P(t)$. If the change in interest rates had no effect on real prices of shelter and non-shelter goods then it should be expected that, after a contractionary monetary policy shock, the impulse response function (IRF) of CPI would be negative because the real prices of both goods would not change. According to our mechanism, after a contractionary monetary policy shock, not only would $P(t)$, the nominal level of the economy, change, but possibly also $R(t)$, the price of shelter services. In order for this effect to generate a price puzzle it would be necessary that the effect of interest rates on $R(t)$, weighed by $(1 - \alpha)$, be larger than the effect of interest rates on $P(t)$:

$$\text{If } \frac{\Delta P(t)}{\Delta i} < (1 - \alpha) \frac{\Delta R(t)}{\Delta i} \implies \frac{\Delta CPI(t)}{\Delta i} > 0 \quad (2.2)$$

From equation 2.2 it is straightforward to see that the smaller the weight of non-shelter goods in total CPI – α – or the larger the response of shelter prices to interest rates, the more likely it is that the overall CPI will increase after a contractionary monetary shock.⁵ This consideration implies that the "size" of the price puzzle may be time varying, which is consistent with the findings of Hanson (2004).

Importantly, and regardless of the overall effect of interest rates changes on total CPI being positive or negative, based on this discussion, for monetary policy conduct and evaluation, the shelter component of the CPI (or PCE, or deflator of GDP) should be excluded if the goal is to measure the nominal state of the economy. In addition, this result also highlights the importance of using data that are model consistent (or vice-versa).

2.4 Data

The data that we use in this paper come from multiple sources. The data used in the main results were collected from the St. Louis Fed Fred economic database. We collected the same four variables used in Sims (1992) – the federal funds rate (FFR), M1 money stock (M1SL), industrial production (INDPRO), and CPI index (CPIAUCSL). In addition, we also collected information for the consumer price index of rent of primary residence (CUSR0000SEHA) and consumer price index of owners' equivalent rent of residence (CUSR0000SEHC), which we use to construct the variable CPI net of shelter. With the exception of the monetary variables (M1SL and FFR), all series were seasonally adjusted and all variables but the federal funds rate are in log levels. Although most of our data ranges from 1960 to 2006, our main empirical results concern the period from 1983 to 2006. We restrict the sample to this period because, as explained in section 2, the CPI suffered a major revision in 1983 that changed the way shelter costs were estimated. In the same methodological revision, housing prices were excluded from the CPI.

Because we perform various robustness checks of our main results and also show how

⁵Although our discussion here is informal, in Chapter 1 we add an endogenous housing tenure choice to a standard New Keynesian model, which allows us to have a more formal and precise discussion of this mechanism.

our results compare to previous explanations of the price puzzle, we had to collect several other data. As alternative inflation measures we use the personal consumption price index (PCE) and the deflator of GDP. The former is observed at a monthly frequency, while the latter is observed at a quarterly frequency. Both were obtained from the St. Louis Fed Fred economic database and cover the period 1960 to 2006. As an alternative measure of monetary policy shocks we use the Romer and Romer. (2004) monetary policy shocks measure, which was updated to a more recent period by Coibion et al. (2012). To replicate the results of Giordani (2004) we used the Federal Reserve Board measure of capacity utilization, which we obtained from the St. Louis Fed Fred economic database. To replicate the results of Brissimis and Magginas (2006) we used the composite index of leading indicators variable that is published by the Conference Board and the expected federal funds rate for the current month.⁶ Finally, in order to implement the FAVAR methodology of Bernanke et al. (2005), we used an updated version of the original dataset covering the period 1960 to 2007 at a monthly frequency.⁷

2.5 Empirical Results

2.5.1 SVAR Model and Identification Strategy

The SVAR model we estimate as well as the shock identification strategy we use in our baseline results, correspond exactly to Sims (1992). That is, we estimate a SVAR model with four variables: federal funds rate, industrial production index, M1 money stock, and some measure of the price level. In the original paper, the author used the CPI as a measure of the price level. In our application, we use the CPI, sub-components of the CPI, and alternative measures of inflation like the PCE and the GDP deflator.

The identification of shocks in the SVAR model used to obtain the baseline results is based on a Cholesky decomposition with the variables ordered as in Sims (1992): federal funds rate, M1 money stock, price variable and industrial production index. In this shock identification

⁶This variable was kindly provided by TradeNavigator.com.

⁷We thank Dalibor Stevanovic for sharing these data with us.

strategy, the first variable contemporaneously affects all other variables; the second variable affects all other variables contemporaneously but the first one; the third variable only affects the fourth variable contemporaneously; and the fourth variable has no contemporaneous effects on the other variables. In section 6 we present results with alternative identification strategies to show that our main result does not depend on using a particular identification strategy.

2.5.2 Main Results

Figure 2.2 summarizes our main result. In this figure we show the impulse response to a positive federal funds rate shock of overall CPI and CPI net of shelter.

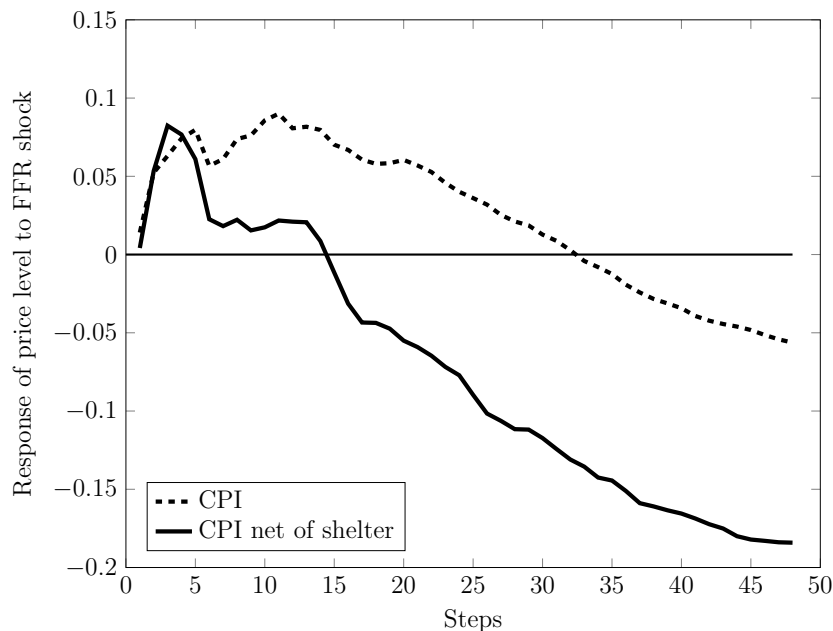


Figure 2.2: Impulse response of CPI and CPI net of shelter to a federal funds rate shock for 1983:01 to 2006:12 period. Shelter only includes primary rent and owner equivalent rent.

The impulse response of overall CPI to an increase of the federal funds rate corresponds to what is perceived as being puzzling and at odds with economic theory. After an increase of the interest rate, CPI is above the baseline level for more than 30 months. In the case where we use CPI net of shelter, we still observe a period of around 14 months where CPI is still above zero, but after 4 to 5 months the level is significantly lower than overall CPI and

after 14 months it actually becomes negative, as would be expected. The reason why even when we use CPI net of shelter we still observe an initial period where CPI is above zero after a contractionary monetary shock is not easy to explain. This initial behavior could be explained by the theory of the cost channel of monetary policy. It is also possible that there are other products for which demand increases after a negative interest rate shock. In order to test the first hypothesis we would need some information about the evolution of marginal costs of production, while to test the second hypothesis we would have to search for products for which prices vary in the same direction as interest rates. Unfortunately, information on marginal costs of production is not easily available, and estimating price elasticities of different product categories to interest rates is something we plan to do in future research. An alternative explanation is that the identification strategy is not the most adequate one and another should be considered. In the next section we perform several robustness check exercises, including using different identification strategies.

Note in Figure 2.2 that, for the first 6 months, the impulse response of both series is very similar, but around 7 months, while the response of CPI net of shelter starts declining, the response of CPI starts increasing and only stops increasing around 11 months. This behavior is consistent with our story but could also be due to some other factor. In order to provide some evidence that this behavior is due to the increase in shelter prices after the contractionary monetary shock, we estimate a four-variable SVAR model where, along with the federal funds rate, industrial production index, and the M1 money stock, we include the shelter price index.⁸ In Figure 2.3 we show the impulse responses of the shelter price index to a contractionary monetary shock.

⁸The shelter price index is the same index that we exclude from the overall CPI to construct the CPI net of shelter series. This series that we call shelter price index does not correspond exactly to what is denominated as shelter by the BLS.

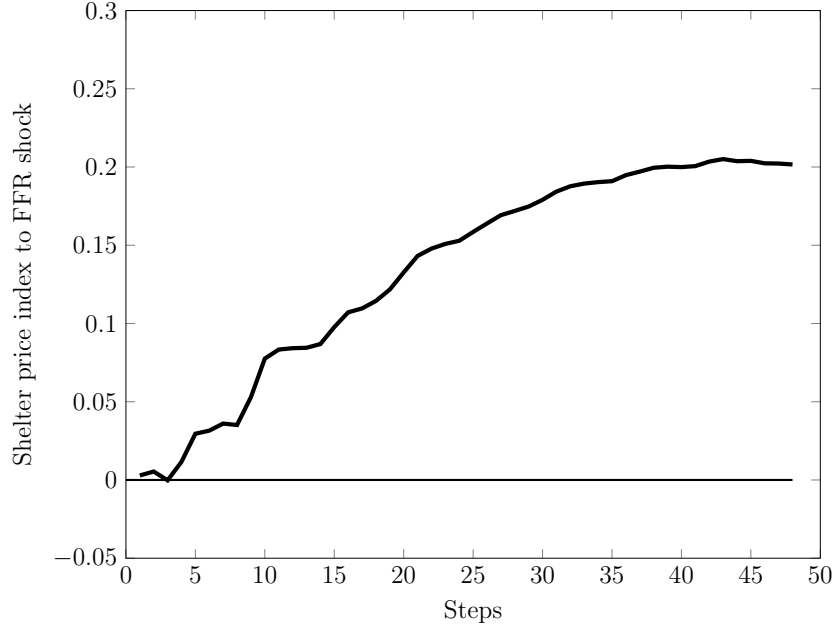


Figure 2.3: Impulse response of shelter to a federal funds rate shock for 1983:01 to 2006:12 period.

The results shown in Figure 2.3 are in line with our interpretation of the behavior of the impulse response of CPI.⁹ The response of shelter prices increases in three distinct periods, around 3, 7 and 15 months. The increase around 3 months does not show in the response of CPI, but the increase around 6 months coincides with the inversion of direction of the impulse response function of CPI. In Figure 2.3 the response of shelter prices continues to increase for almost 3 years while in Figure 2.2 the response of CPI peaks at 11 months. Because the impulse response function is not linear, and because it depends on the behavior of all variables in the system, the impulse response of CPI and shelter do not need to be fully consistent with our story. Yet, in our view, both variables show a behavior in the first periods of the response that is consistent with our story and with our interpretation of the inversion of direction of the impulse response for CPI.

Two important questions that we have not addressed so far are whether the two impulse response functions in Figure 2.2 are statistically different from each other and whether the responses of the other variables in the model are similar when CPI or CPI net of shelter

⁹The result shown in Figure 2.3 is basically the same result shown in Duarte and Dias (2015), which led us to write the present paper.

are used. To answer these questions properly we would need to be able to compare impulse response functions from non-nested models in a statistical way. Unfortunately, to the best of our knowledge, there are no such tests and therefore the best we can do is show the various impulse responses and let the reader judge for him/herself. In Figure 2.4 we show the impulse responses with corresponding 68% confidence bands of all the variables included in the SVAR model to a contractionary monetary policy shock.

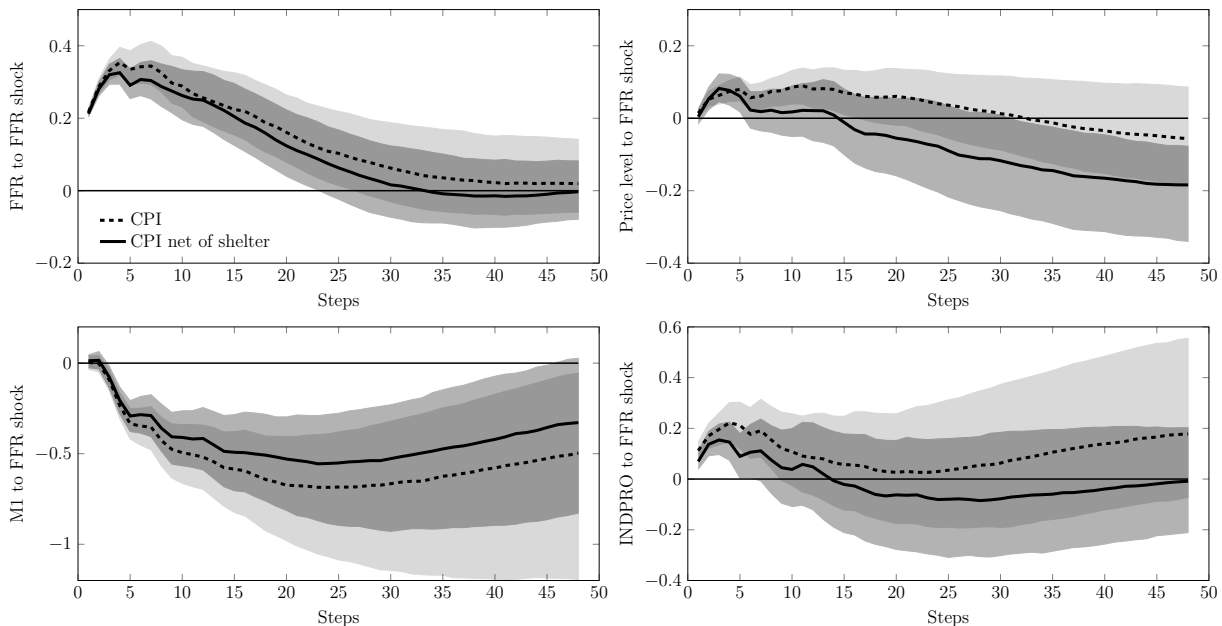


Figure 2.4: Impulse responses to a federal funds rate shock for 1983:1 to 2006:12 period. Both shaded areas represent the 68% confidence intervals. The light area is associated with the CPI, the medium area with the CPI net of shelter, and the darker area with the intersection of the two.

With the exception of the responses of CPI and CPI net of shelter, the responses of the other three variables are qualitatively similar in both specifications. We interpret this similarity as evidence that our result is not driven by some strange response of one or more variables included in the model. Also interesting to note is that only in the cases of CPI and CPI net of shelter the 68% confidence bands of the two impulse response functions do not overlap for most of the response horizon. We acknowledge that comparing the confidence bands of two impulse response functions is not a formal test, but the fact that for CPI and CPI net of shelter the two impulse response bands do not overlap is consistent with our interpretation of the results. That is, the responses of CPI and CPI net of shelter to a

contractionary monetary policy shock are economically different.

An additional interesting result regards the forecast error variance decomposition of the two variables (CPI and CPI net of shelter). In Table 2.1 we show the forecast error variance decomposition up to 48 periods. Although the two decompositions are not too different from

Forecast error variance decomposition					
CPI					
Step	Std Error	FF	M1	CPI	INDPRO
1	0.173	0.6	1.1	98.3	0.0
8	0.585	7.7	1.5	85.3	5.5
16	0.976	7.1	2.1	80.1	10.7
24	1.275	5.4	3.4	79.1	12.1
32	1.482	4.1	4.9	78.7	12.3
40	1.629	3.5	6.2	78.2	12.1
48	1.737	3.6	7.2	77.6	11.6
CPI net of shelter					
Step	Std Error	FF	M1	NETCPI	INDPRO
1	0.246	0.0	1.4	98.6	0.0
8	0.804	2.8	1.8	90.8	4.6
16	1.328	1.2	4.0	85.3	9.5
24	1.709	1.5	7.3	81.4	9.8
32	1.951	3.5	10.6	77.5	8.4
40	2.123	6.7	12.9	73.2	7.2
48	2.264	10.6	13.8	69.0	6.6

Table 2.1: Forecast error variance decomposition of CPI and CPI net of shelter.

each other, the decomposition of CPI net of shelter puts a smaller weight in the contribution of industrial production, and more on the other three variables – 11.6% after 48 periods in the case of CPI and only 6.6% in the case of CPI net of shelter. Since inflation is inherently a nominal variable, it is sensible that in the long run it is mostly driven by nominal shocks and not by real shocks.

2.6 Robustness Checks

2.6.1 Alternative Identification Strategies

As mentioned previously, the identification strategy that we use to obtain the main results is not unique and other strategies could be justified. We do not have a strong preference for a particular identification strategy. Instead, we are mostly concerned about showing that our results do not depend on the identification strategy that is used. In this regard, we try two different orderings of variables in the SVAR model.

It is difficult to argue that the monetary authority knows the price level and industrial production when using monthly data. Still, the monetary authority has weekly and daily information on variables that can give an idea of what is happening with the price level and industrial production in any given month. In particular, the BLS typically collects price data in the middle of the month while the Federal Open Market Committee (FOMC) meets either in the middle or at the end of the month. We present here two different orderings: one where the monetary authority observes contemporaneously industrial production and the price level, as in Christiano et al. (1996), and one where it just observes the price level. Results of these two alternative identification strategies are presented in Figures 2.5 and 2.6, respectively.

From Figures 2.5 and 2.6 we conclude that our baseline results do not depend on the ordering of the variables in the VAR since alternative variable orderings generate results that are qualitatively similar. That is, not only does the response of CPI net of shelter become negative much faster than the response of CPI, but we also observe that the response of CPI inverts the direction around 7 months.

Given the recursive identification approach, it can be argued that the identification of the monetary policy shock is different when using CPI net of shelter instead of CPI. The monetary policy authority certainly responds to CPI but the same cannot be claimed for CPI net of shelter. One way of accommodating this criticism is to use the Romer and Romer. (2004) measure of monetary policy shocks (updated to a more recent time period by Coibion et al. (2012)). As argued by Romer and Romer. (2004), this measure of monetary shocks is

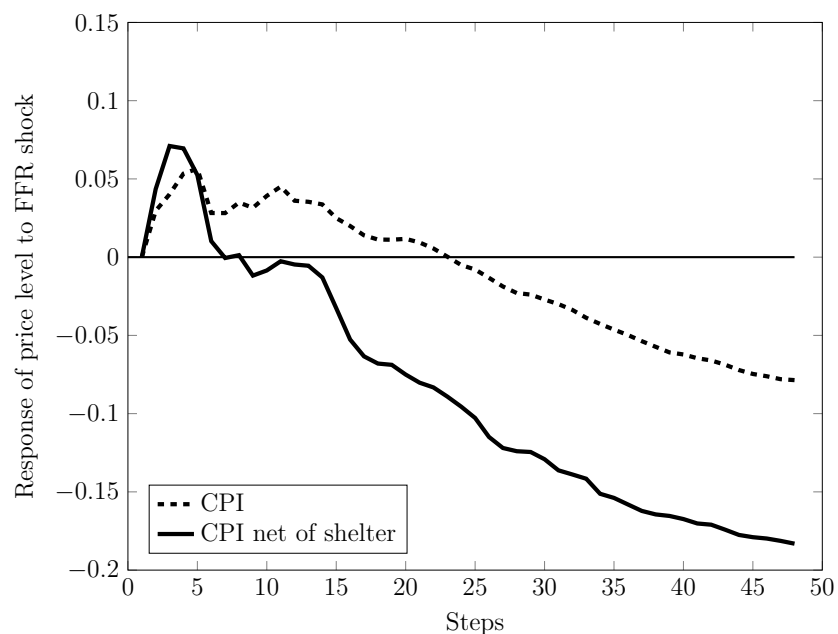


Figure 2.5: Impulse response of CPI and CPI net of shelter to a federal funds rate shock from 1983:01 to 2006:12 period for alternative ordering: industrial production, price level, interest rate, and money aggregate.

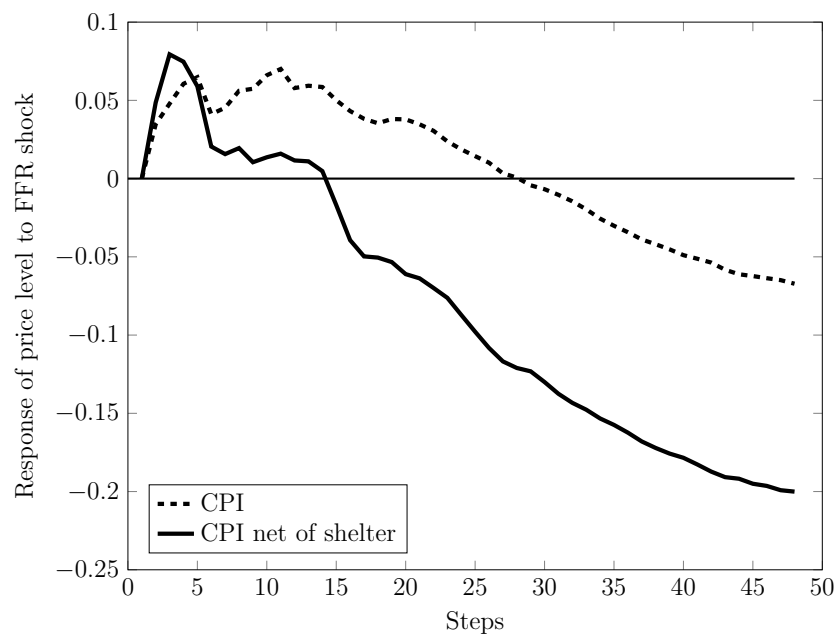


Figure 2.6: Impulse Response of CPI and CPI net of shelter to a federal funds rate shock from 1983:01 to 2006:12 period for alternative ordering: price level, interest rate, money aggregate, and industrial production.

robust to anticipatory and endogenous actions of the monetary policy authority. In this way, we can compare responses of CPI and CPI net of shelter that use the same identification. The corresponding results are shown in Figure 2.7.

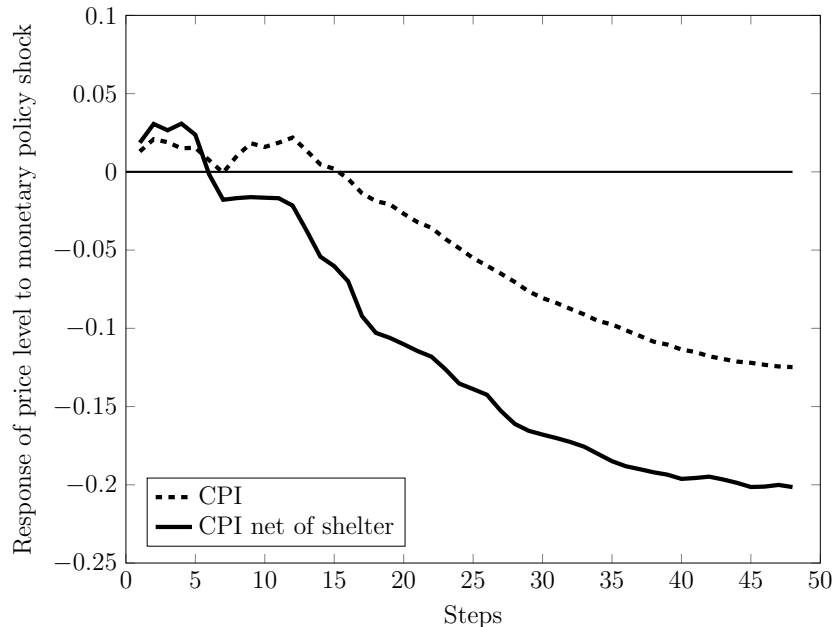


Figure 2.7: Impulse response of CPI and CPI net of shelter to a monetary policy shock (Romer and Romer. (2004) and Coibion et al. (2012)) 1983:01 to 2006:12 period.

The same qualitative results are obtained once again. However, some differences are observed. The price puzzle is "smaller" for CPI than when a recursive identification is used. This result is not new; it has already been reported in Romer and Romer. (2004). With this identification, nevertheless, we still see the same ordering of impulse responses we saw previously. The response of CPI stays positive for a longer period than the response of CPI net of shelter – approximately 15 months for the former and approximately 5 months for the latter. Hence, there is a difference of almost a year between the two different measures in terms of positive response and of approximately 0.1 standard deviations in terms of quantitative difference from 15 months forward.

2.6.2 Alternative Measures of Inflation

To show that our results do not depend on the measure of the price level that is used, we estimate the same model used to obtain our baseline results, but instead of using CPI, we use the PCE and the GDP deflator. Figures 2.8 and 2.9 show the results when the PCE and the GDP deflator are considered, respectively.

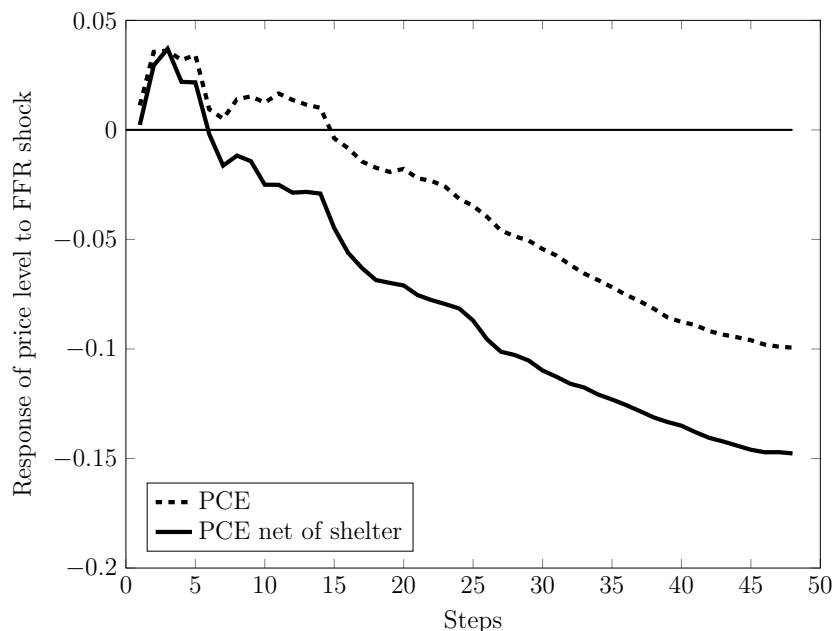


Figure 2.8: Impulse response of PCE and PCE net of shelter to a federal funds rate shock from 1983:01 to 2006:12 period. Shelter only includes primary rent and owner equivalent rent.

Similar to what was observed in Figure 2.2, we see in Figures 2.8 and 2.9 that when we exclude shelter from the price index (PCE or GDP deflator) the response of prices to a contractionary monetary policy shock becomes negative much faster than when shelter is included.

In the case of the PCE, the result based on overall PCE is already quite satisfactory, as after 15 months the impulse response crosses the zero line and becomes negative. However, despite the initial result not being as strange as in the case of the CPI, when we use PCE net of shelter a measure of the price level the impulse response becomes negative after 6 months, which is much quicker than in the case of overall PCE. It is important to notice that the initial result is not as strange as in the case of CPI because the weight of shelter in the PCE

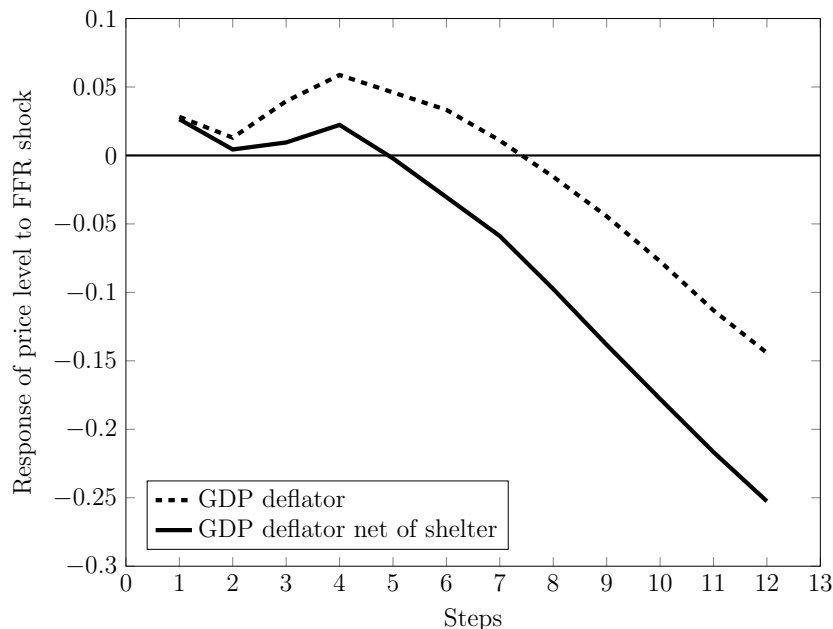


Figure 2.9: Impulse response of GDP deflator and GDP deflator net of shelter to a federal funds rate shock from 1983:01 to 2006:4 period for quarterly data. Shelter only includes primary rent and owner equivalent rent.

is only 15% while it is close to 30% in CPI. Besides the difference in the weight of shelter, the PCE also differs from the CPI in terms of how the weights used in the computation of the index change over time. In the CPI, these weights are fixed for a fairly long period of time (more than 1 year). In the PCE, the weights used in its computation adjust every month based on the quantities consumed of each good or service.

For the GDP deflator, we also obtain a similar result. When we exclude shelter from this price index, the impulse response becomes negative more quickly (between three and four quarters) than when shelter is included.

2.6.3 The Original Puzzle Dissected

As explained previously, in 1983 there was a major revision in the methodology used in the construction of the CPI. Among other changes, the concept of owners' equivalent rent was introduced and the cost of home ownership item was removed from the index. This change brings naturally the investigation of the pre-1983 period as a robustness check. Figure 2.10 shows results based on the sample used in the original article as well as results for two sub-

samples – before and after 1983. Given our previous discussion, it would be expected that the price puzzle would be "worse" after 1983 because that corresponds to the period with a higher weight of shelter. This hypothesis is confirmed in Figure 2.10, where it can be seen that the CPI impulse response function is positive for more than 48 months. Also interesting is that only in the post-1983 sample is a change of direction of the impulse response function observed. This inversion of direction also takes place at around 8 months, and the impulse response stabilizes around month 13/14. Regarding the pre-1983 sub-period we observe a slightly "smaller" puzzle than the original.

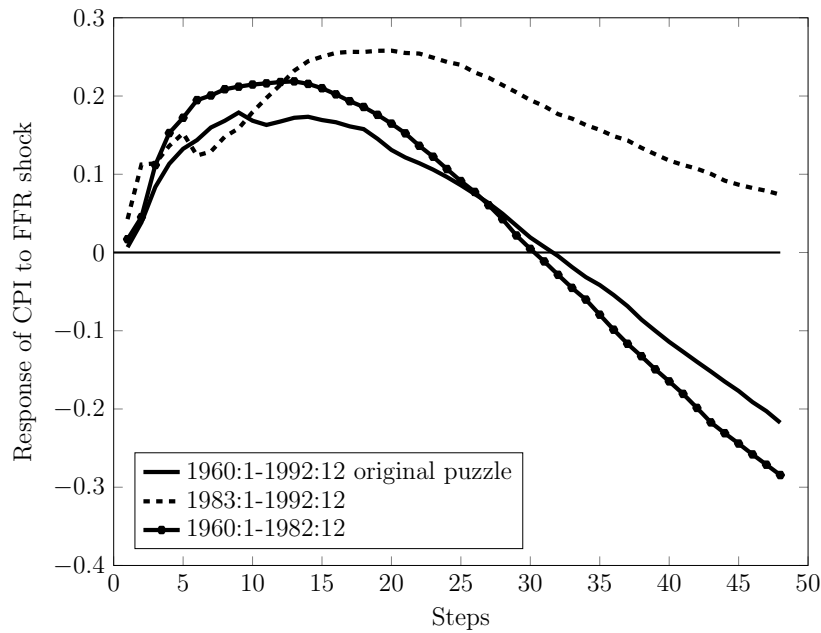


Figure 2.10: The original price puzzle presented in Sims (1992) and its breakdown in the before and after 1983 sub-periods.

If we compare the original puzzle with the puzzle presented in our main results, it is possible to see how similar they are. Both become negative around 35 months. However, the positive response is stronger in the original puzzle than the response of CPI shown in Figure 2.2. In the original puzzle, the positive response peaks at more than 0.2% while in our baseline result peaks at less than 0.1%. This result seems to be at odds with our mechanism since the original puzzle was based on a sample where housing shelter had less weight (around 6%) and housing prices were part of the CPI. This motivates breaking down the period pre-1983 to investigate what dynamics are in place.

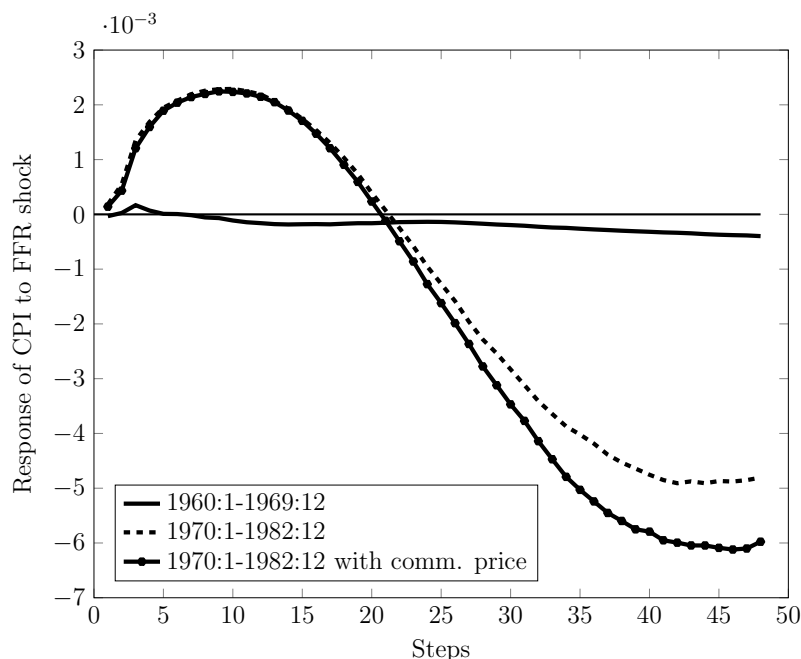


Figure 2.11: The 1960-1982 period and its breakdown between the pre- and stagflation decades.

Figure 2.11 shows the breakdown in two sub-samples. From 1960:1 to 1969:12 the result is what would be expected if the mechanism proposed in this paper was relevant. That is, in a period where house rents had a very small weight in overall CPI, the response of prices to a contractionary monetary shock is negative, as theory would predict.

The results presented in Figures 2.10 and 2.11 seem to suggest that the original puzzle was mainly driven by the 1970:1 to 1982:12 period and the change in the calculation of shelter costs. It is well known that the 1970s was a turbulent period in economic terms with the occurrence of oil shocks, high inflation, and experimentation with monetary policy. The fact that the original puzzle is partially driven by the 1970:1 to 1982:12 period helps in understanding why the inclusion of commodity prices helped explaining the puzzle, but this link disappeared in more recent periods, as was pointed out by Hanson (2004). However, in Figure 2.11 we can see how using the commodity prices did not correct much of the puzzle even for the 1970:1 to 1982:12 period. This finding is similar to Romer and Romer. (2004), who show how small the response of the price level is to monetary policy shocks (their own measure and actual federal funds rate) when commodity prices are included. One

final remark about the results in Figures 2.10 and 2.11 is that for all cases where a pre-1983 sample was used, we do not observe an inversion of the CPI impulse response function. That is, in these cases, there are no instances in which the impulse response starts declining and then starts increasing again, as was the case for impulse responses based on post-1983 samples.

2.7 Alternative Explanations of the Price Puzzle

As discussed in the introduction, there are several explanations for the price puzzle, each with its own merits. We do not want to discuss whether our explanation is better than existing ones nor take a stand on which explanation is our preferred one. Instead, we want to see how our explanation fits with existing ones. To do so, we replicate some of the leading explanations of the price puzzle incorporating our idea. We choose four alternative explanations: 1) exclusion of a measure of output gap — Giordani (2004); 2) exclusion of forward looking variables — Brissimis and Magginas (2006); 3) insufficient controlling for other variables used in the information set of the central banker — FAVAR model of Bernanke et al. (2005); 4) theory based – sign restriction method of Uhlig (2005).¹⁰

2.7.1 Output Gap

Giordani (2004) argues that the SVAR model used by Sims (1992) is misspecified, and this misspecification lead to a spurious price puzzle. The source of the misspecification is the inclusion of a measure of GDP (or industrial production) instead of using a measure of output gap. In Figure 2.12 we show the impulse response function of CPI and CPI net of shelter to a contractionary monetary policy shock in the context of a model with output gap (left panel) and with GDP (right panel). As is visible in Figure 2.12, the SVAR model with output gap delivers results where there is almost no price puzzle for both CPI and CPI net of shelter, but it also shows that CPI net of shelter responds more negatively than CPI

¹⁰To be fair to the author, the main goal of Uhlig (2005) is to study the effects of monetary policy shocks on output, and in order to better identify monetary policy shocks, the author imposes restrictions on the response of prices.

to the same monetary shock. In the case of the SVAR model that uses GDP, the response of CPI is always positive for the first four years, while the response of CPI net of shelter becomes negative after two years. These results make it very clear that the point made by Giordani (2004) is important, but the results also show that using the response of inflation to monetary shocks is quicker than what is implied by the response of CPI. From our discussion in section 2, the fact that rents increase after a contractionary monetary policy shock does not always lead to a price puzzle, but the response of CPI is always a combination of two distinct responses: the response of the shelter and the non-shelter components of CPI.

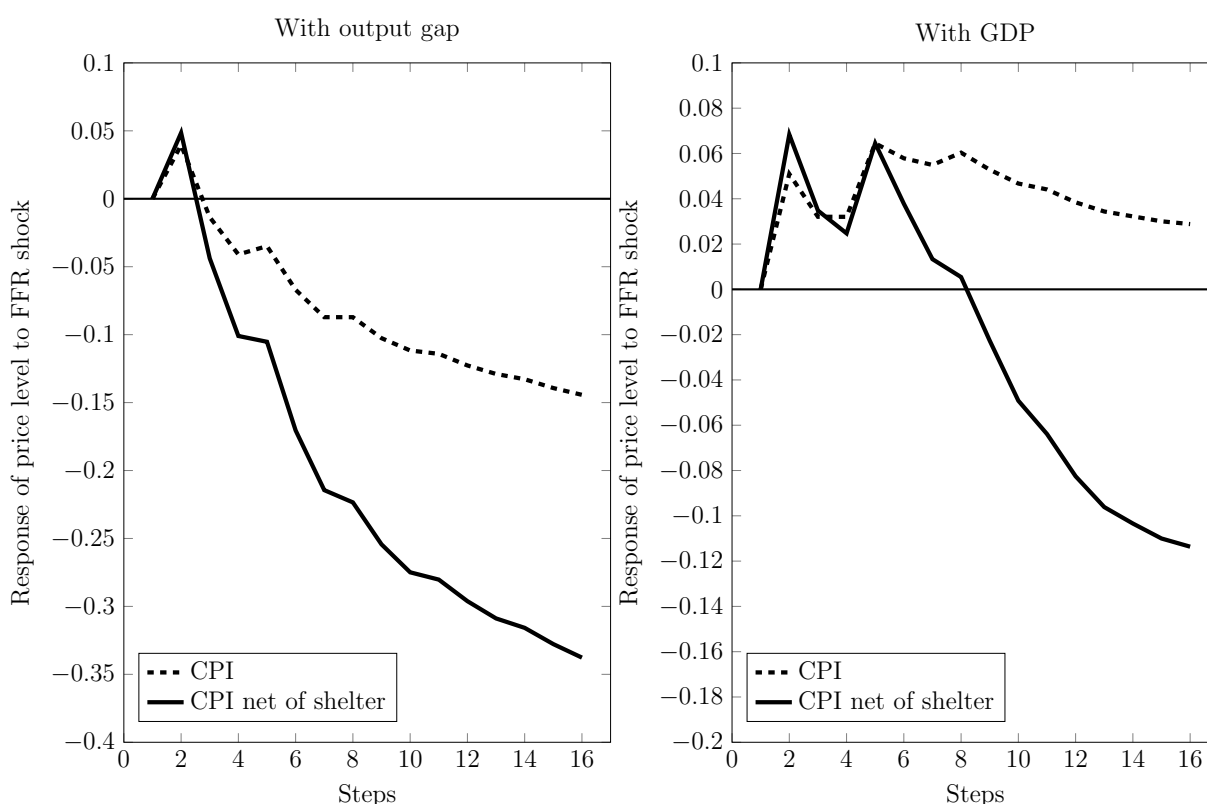


Figure 2.12: Impulse responses to a federal funds rate shock for 1983:1 to 2006:4 period with an output gap measure as in Giordani (2004). The left panel reports the response of price level to the full specification with output gap and the left panel with GDP instead of output gap.

2.7.2 Forward-Looking Variables

Brissimis and Magginas (2006) also argue that the original SVAR model used by Sims (1992) is misspecified. According to these authors, the Sims (1992) SVAR model is misspecified because it does not include any forward-looking variable to help with the identification of shocks. To correct this misspecification, the authors add to the SVAR model of Sims (1992) a measure of expected economic activity and a measure of expected interest rates. The measure of expected economic activity is treated as endogenous, while the second is treated as exogenous. We replicate this approach with both CPI and CPI net of shelter (Figure 2.13). We consider the cases of adding both variables to the empirical, and only adding the expected economic activity variable. Similar to Giordani (2004), the new model specification defended by Brissimis and Magginas (2006) improves the results significantly. At the same time, we also find a similar result to what we showed in the previous sub-section. That is, the response of CPI net of shelter is much quicker than the response of CPI and, in the case of just using the expected economic activity indicator, the response of CPI net of shelter becomes negative before the response of CPI.

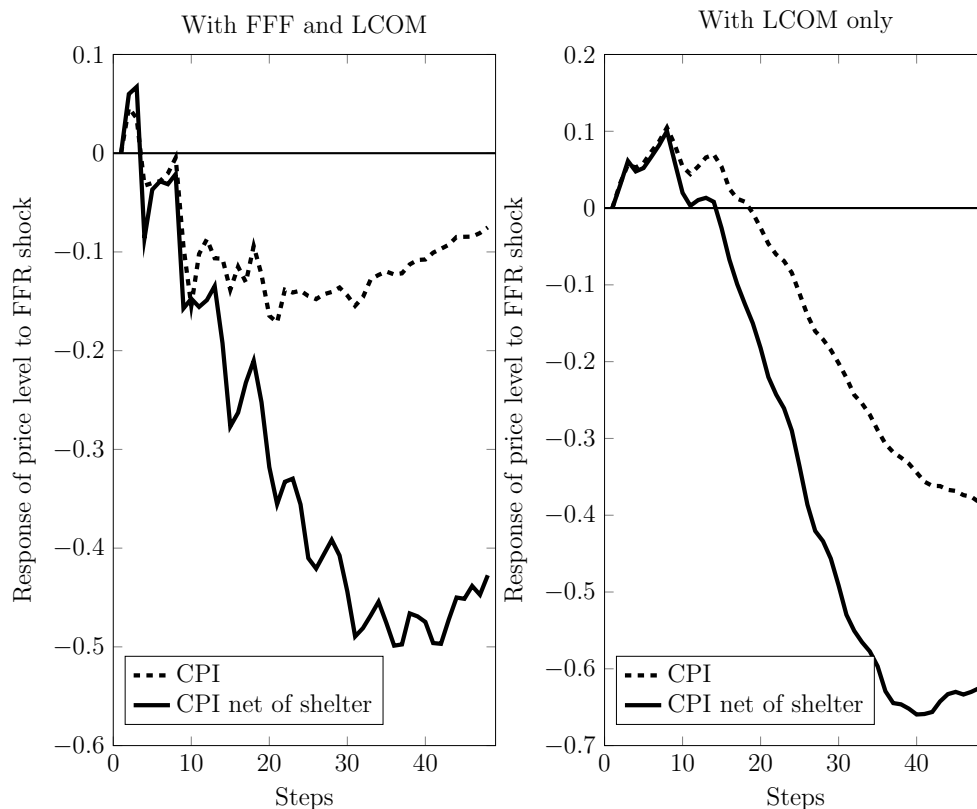


Figure 2.13: Impulse responses to a federal funds rate shock for 1989:1 to 2006:12 period with forward-looking information variables as in Brissimis and Magginas (2006). The left panel reports the response of price level to the full specification with federal funds futures rate (FFF) and composite leading indicator of economic activity (LCOM). The right panel only includes LCOM.

2.7.3 FAVAR

Bernanke et al. (2005) propose a new econometric method that allows for richer information environments while keeping the model fairly parsimonious. This model is known as a factor augmented vector autoregressive (FAVAR) model. The basic idea is to condense a large set of variables into just a few number of factors and then use these factors and other variables of interest in a SVAR model. One of the by products of this new approach is that the impulse response of CPI to a contractionary monetary policy shock is much more in line with economic theory. To show that our result still holds, we replicate the results of Bernanke et al. (2005) using data from 1959:01 to 2006:12 together with the variable CPI net of shelter, which only covers the period from 1983:01 to 2006:12. The impulse responses

to a contractionary monetary policy shock of CPI and CPI net of shelter based on a FAVAR model are shown in Figure 2.14.¹¹

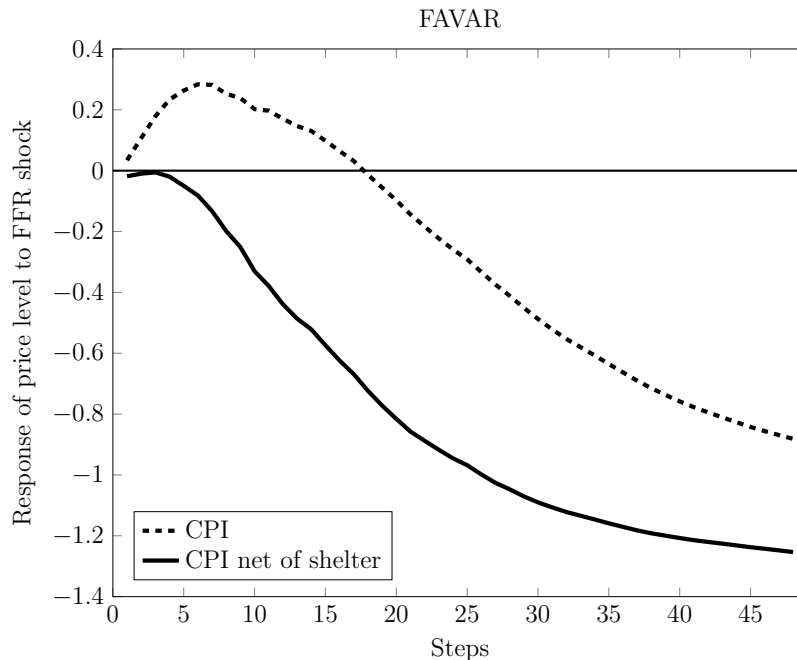


Figure 2.14: Impulse responses of CPI and CPI net of shelter to a federal funds rate shock for 1959:01 to 2006:12 period using a three factors FAVAR model as in Bernanke et al. (2005) while adding CPI net of Shelter to the sample.

The results could not be clearer. In the case of the response of CPI, although it turns negative more quickly than in our baseline case (Figure 2.2), it still takes about 18 months to become negative. At the same time, the response of CPI net of shelter is never positive and it corresponds to what theory predicts.

Despite this result being very favorable to our main point, we must acknowledge that the comparison of the two responses is somewhat unfair because the two variables cover different time periods. In the case of CPI it includes the period of the 1970s which is known to be a conturbated period. In Figure 2.15, we show the impulse response of CPI net of a shelter and of CPI pre-1983 and post-1983.

¹¹CPI net of shelter is only defined for the period from 1983:01 to 2006:12 because the concept of owner equivalent rent was only introduced in 1983. However, the method allows us to use variables with different time periods.

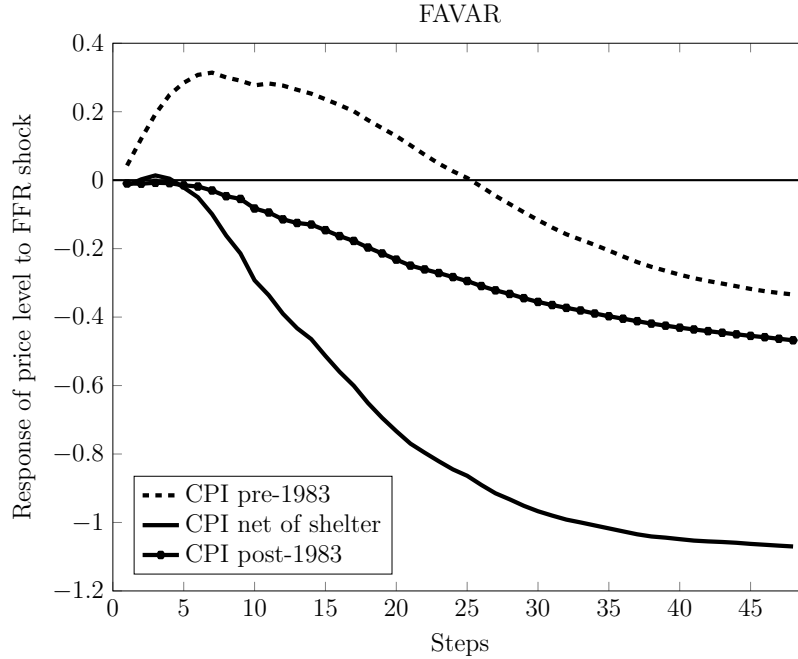


Figure 2.15: Impulse responses of CPI pre-1983, CPI post-1983 and CPI net of shelter to a federal Funds Rate Shock for 1959:01 to 2006:12 period using FAVAR with three factors and sample just as in Bernanke et al. (2005) while adding CPI net of shelter to the sample.

In this case, the response of CPI pre-1983 takes more than two years to become negative, while the response of CPI post-1983 is always negative. In the case of CPI net of shelter, the result is basically the same as in Figure 2.14. We would like to highlight the fact that, once again, there is a considerable difference in the responses of CPI and CPI net of shelter, with the latter being more responsive than the former.

2.7.4 Sign Restriction

Finally, we show how the results change when a pure sign restriction is used as an identification strategy. In this case, the monetary policy shock is identified by restricting the signs of selected impulse functions for a fixed number of periods. We follow Uhlig (2005) and eliminate the price puzzle by construction by restricting the interest rate response to be positive, the price level to be negative, and money aggregate to be negative for five months. We leave the industrial production response unrestricted. Hence, this is an agnostic identification with respect to output. This alternative identification is important to help separate

the misspecification problem of our mechanism. Figure 2.16 shows the results.

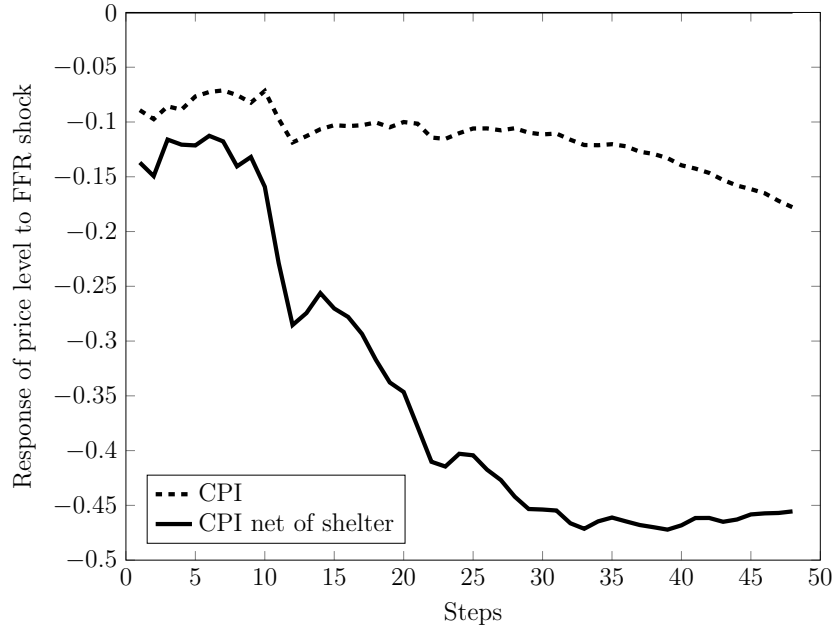


Figure 2.16: Pure sign restriction agnostic with respect to output. Impulse response functions sign restricted for five months ($k = 5$). The variables restricted are the same as in Uhlig (2005) with interest rate being positive, money aggregate negative, and CPI negative for the restricted periods. 1983:01 to 2006:12 period.

We see once again a sharp difference in the response of CPI net of shelter in comparison to the response of CPI. These results are not directly comparable to the ones presented previously, but they share at least one important common feature: CPI net of shelter responds more quickly to a monetary shock than overall CPI.

When some variable is not model consistent and a pure sign restriction is used the results obtained may be hiding some important issues. By digging deeper, we were able to unveil an important feature of the CPI that we believe to be very important for monetary policy.

2.8 Conclusion

In this paper we take into account the effects of monetary policy on housing tenure choice and the weight of shelter in the CPI to explain the price puzzle. After an increase in interest rates, more people will want to rent instead of own and this shift in consumption behavior

increases the price of rents in comparison to all other goods. We provide a simple theoretical framework (the effect of monetary policy on housing tenure choice) for why housing rents may increase after a contractionary monetary policy shock. This mechanism is different from the cost channel literature, and our empirical results suggest that it is relevant in explaining the price puzzle. Our results are qualitatively robust to different identification strategies, measures of inflation, sample periods, and they compare well against alternative explanations.

In our opinion, these results would be interesting on their own, but they may be significantly more far-reaching than just explaining the price puzzle. While providing a possible explanation for the price puzzle, we showed that, when we exclude shelter from the CPI, inflation seems to be much less persistent than previously thought. More generally, the results of this paper highlight the importance of measuring inflation in a theoretically consistent way to better separate price changes caused by inflation from price changes caused by relative price changes.

CHAPTER 3

SERVICE SECTOR'S PRODUCTIVITY DIFFERENCES BETWEEN EUROPE AND US: WHY IS EUROPE FALLING BEHIND?

3.1 Introduction

Average annual labor productivity growth (measured as GDP per hour of work) in the United States accelerated from 1.2 percent in the 1973-1995 period to 2.3 percent from 1995 to 2006. Conversely, the 15 European Union countries that constituted the union up to 2004 experienced a productivity growth slowdown between these two time periods. Slower labor productivity growth in Europe than in the United States since 1995 reverses a long-term pattern of convergence. One of the key questions is what factors are behind this large difference in productivity growth between Europe and the US? Moreover, how can they help explain the slowdown in productivity growth in Europe relative to the US?

The objective of this paper is to identify factors that can explain differences in the service sector's productivity between Europe and the US. Our approach to identify these factors is two-folded. First, we break down the service sector and extend a standard structural transformation model of Duarte and Restuccia (2010) to investigate how the structural transformation within the service sector affects the labor productivity of the service sector. We show that indeed a compositional analysis of the service sector reveals that the differences in the service sector's productivity between Europe and the US are the result of differences in labor productivity in trade, food and accommodation, transportation, storage and communication. Second, we explore the EU KLEMS data set to empirically investigate if differences in labor market regulation help explain the differences in the service sector's productivity. Our preliminary results suggest that labor market regulation associated with

Joint work with Cesare Buiatti and Luis Felipe Sáenz.

labor market rigidity is negatively correlated with service labor productivity.

Inklaar et al. (2008) give an initial analysis on the subject and provide some insights on what factors might be behind these differences in productivity between Europe and US. They find that the most important factors are the lower growth contributions from investment in information and communication technology in Europe, the relatively small share of technology producing industries in Europe, and slower multifactor productivity growth. In particular, they find that this effect is more notorious in the service sector. Hence, the authors conclude that the service sector is the major issue in Europe's slowdown of labor productivity and suggest that further investigation of the productivity differences between US and Europe should be centred around the service sector.

Duarte and Restuccia (2010) provide further evidence that the differences in the service sector's productivity across countries help explain the differences in aggregate productivity. They constructed a structural transformation model in order to build comparable measures of productivity across different countries. However, the question remains. What are the factors that help explain differences in service sector's productivity? In this paper we shed light on what factors are potentially important in explaining these differences.

The rest of the paper is organized as follows: in section 3.2 we show and discuss the stylized facts of structural transformation of the economy and within service sector; in section 3.3 we present a simple conceptual framework that extends the standard structural transformation model to include service sub-sectors; in section 3.4 we show our preliminary empirical work on labor regulation and service sector labor productivity ; and in section 3.5 we conclude.

3.2 Stylized Facts

The European countries experienced a strong catch up with the US in aggregate labor productivity between the 70's and 90'. However, at some point in the 90's this process was halted and the trend of catch up was replaced by one of retrogress. The experience of the relative performance in labor productivity of our sample European countries can be seen in Figure 3.1. It is clear that for the European Countries, besides Netherlands, there was a large change in trend in the relative performance to the US in labor productivity. What

could potentially be behind such a dramatic change in relative performance?

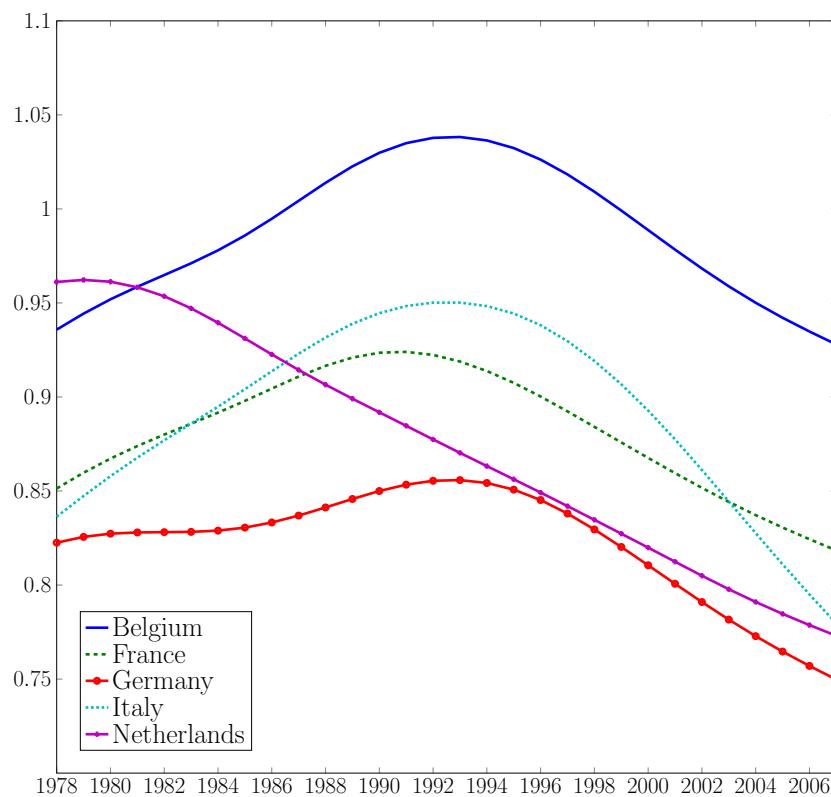


Figure 3.1: Relative GDP per employment in each European country relative to that of the United States.

Looking at the question through the lens of structural transformation, Duarte and Restuccia (2010) show that the answer seems to be in the lack of catch up in labor productivity of the service sector by the European countries. These countries are at a late stage in the structural transformation process, thus with a high labor share allocated in the service sector (Figure B.1 in appendix B). At the same time, the labor productivity in services is remarkably different between the US and Europe, with the European countries being much less productive in levels and growth rates. When combining both facts, Duarte and Restuccia (2010) showed that most of the lack of catch up in the aggregate productivity between European countries and US can be explained by the lack of catch up in labor productivity in the service sector.

Why is the service sector labor productivity in European countries falling behind the US? This is the main question of interest in this paper. Our strategy to answer this question is

going to be built upon two observations. The first observation is that the service sector is very heterogeneous, and the second observation is that labor market regulation is remarkably different between the European countries and the US. Labor market regulation that affects labor rigidity can affect labor productivity. For example, a firm that hires an employee that is not productive but that because of labor rigidity is hard to fire can reduce the overall productivity of that specific firm. We explore if indeed the differences in labor regulation help explain the service sector's labor productivity differences in section 3.4. In the next section we explore the first observation by breaking down the service sector and investigate what types of services are more responsible for the lack of catch up in labor productivity of the service sector.

3.2.1 Breaking Down the Service Sector

Using the EU KLEMS¹ data, we break down the service sector into four sub-sectors: Trade, food and accommodation (TFA); transportation, storage and communication (TSC); finance, real estate and business (FRB); and government and others (GO). Trade, food and accommodation includes whole sale and retail, while government and other include personal, health and education services. The service sector could potentially be even more disaggregated as these for sub-categories still have a great deal of heterogeneity. However, data limitation only allows us to reach this disaggregation level. We first show the structural transformation of each service sector sub-category across countries, and secondly we show the labor productivity for each sub-category across countries.

A. Service Industries Labor Allocation Across Countries

The structural transformation within the service sector varies across different sub-categories. From Figure 3.2, one can conclude that the rise in the service sector labor share has been driven mostly by finance, real estate business, government and others. In other words, from the labor that has been allocated to services, most of it has been allocated to finance, real

¹For more details on this data set, see O'Mahony and Timmer (2009).

estate and business, and government and others. At the same time, very few new labor that is allocated in services is allocated to transportation, storage and communication, and trade, food and accommodation. In fact, the labor share in TSC has gone down for the US.

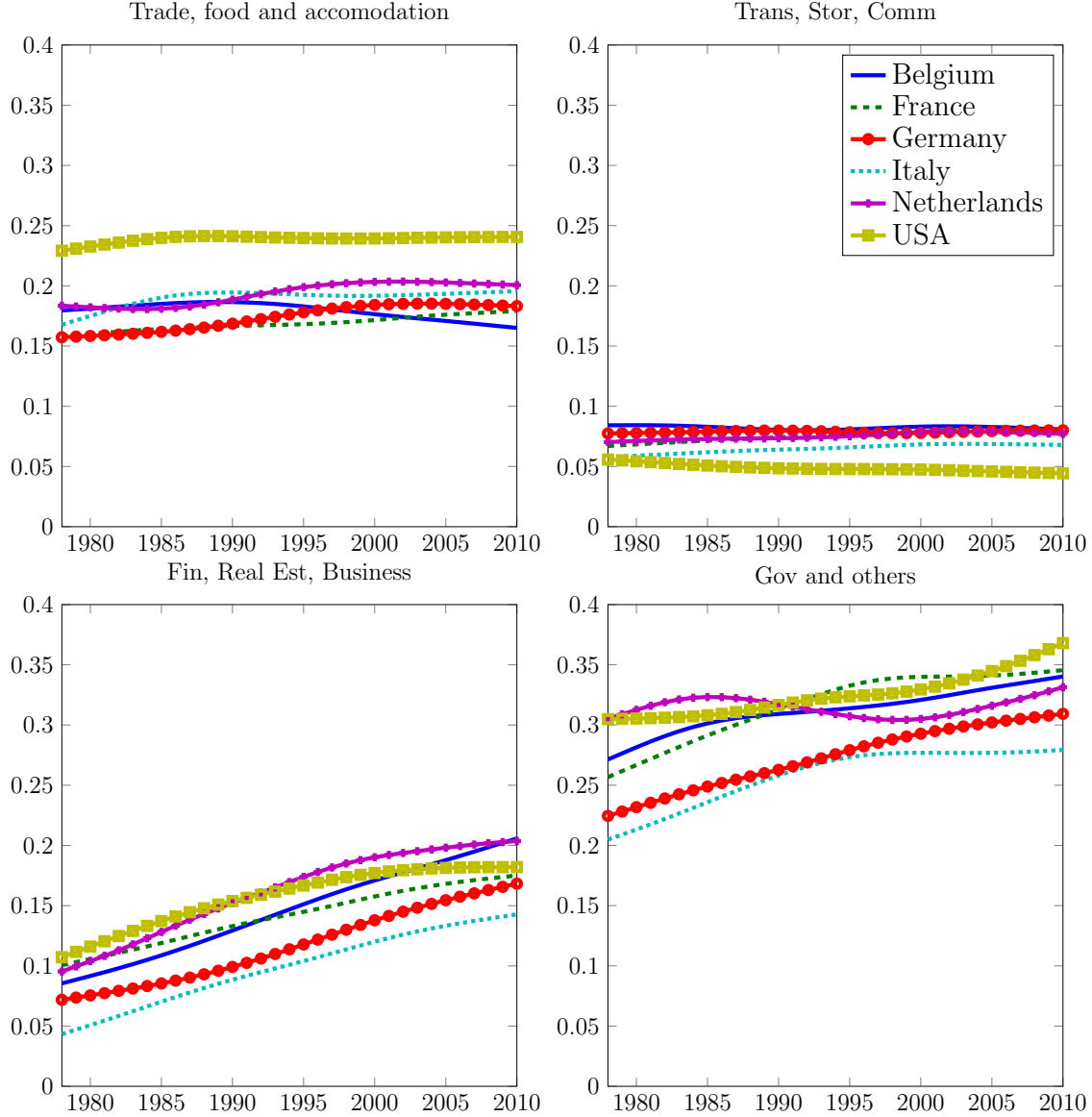


Figure 3.2: Labor shares as a percentage of total employment in the economy for each service sub-sector.

In addition, although the trends of structural transformation are similar across countries, the levels are different. For instance, the US has the highest labor share in TFA by a large margin and the lowest in TSC. The US has approximately 7% more of total labor allocated to TFA than Germany. Hence, even if labor productivity of each specific sub-category was

the same across countries, this disaggregated structural transformation of the service sector could explain why the aggregate service sector labor productivity is different across countries and how it changed over time.

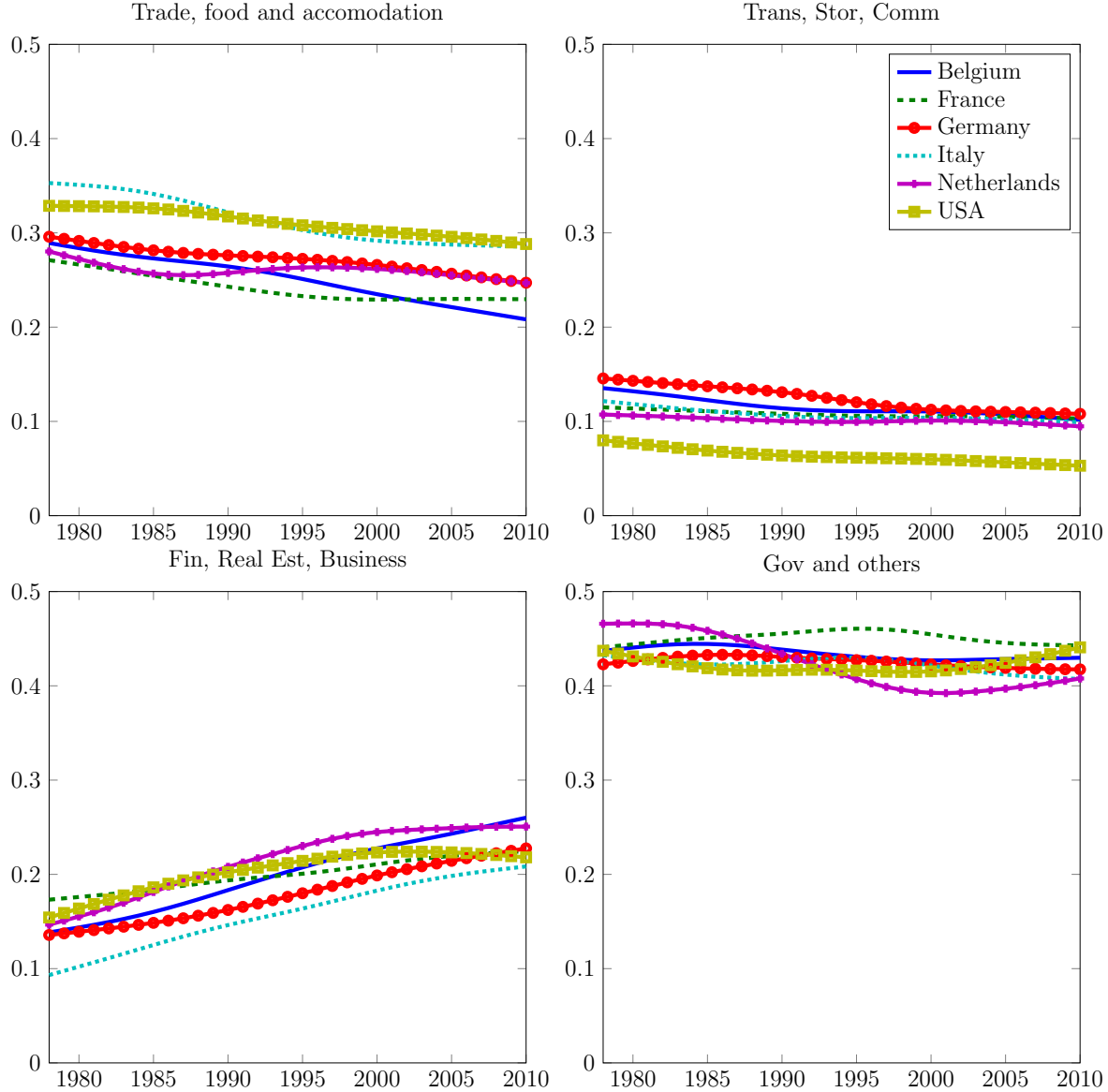


Figure 3.3: Labor shares as a percentage of service sector total employment for each service sub-sector.

In order to see how the labor allocation of each sub-category changed relative to services only, we plot the labor share as a percentage of service total employment instead of the economy total employment in Figure 3.3. Inside the service sector, TFA and TSC have

been reducing their importance in total service employment from 1978 to 2010, while GO have been stable, and finally FRB has increased substantially its share in service total employment. From this figure, it is clear that GO constitute the largest share of services in our sample economies, being almost half of total services and stable over time. Hence, one can conclude that from the labor allocated to services, approximately half of it has been allocated to GO over time.

Structural transformation studies the allocation of labor between agriculture, manufacturing and services, and in this paper we test whether the same forces that drive structural transformation could also help explain the allocation of labor across service sub-sectors. If a substitution effect is taking place between service sub-sectors like in Ngai and Pissarides (2007), we could potentially explain the allocation of labor of the service sub-sectors by looking at the paths of labor productivity of these same sub-sectors. We will test this idea in the future with a calibrated version of the model proposed in this paper. For now, we will show in the next section the labor productivity growth rate of each sub-category across country.

B. Service Industries Productivity Across Countries

The United States has the highest annualized growth rate of service labor productivity between 1978 and 2010 at approximately 1.3%. One way to understand why this is the case is to analyse the labor productivity growth of each sub-category of the service sector. Figure 3.4 plots the annualized growth rate of labor productivity in each service sub-sector against the annualized growth rate of aggregate service labor productivity for all countries in our data set. The service sub-sectoral growth rate of the United States in each scatter plot is identified by the horizontal dashed line, whereas the vertical dashed line marks the growth rate of aggregate service labor productivity of the United States.

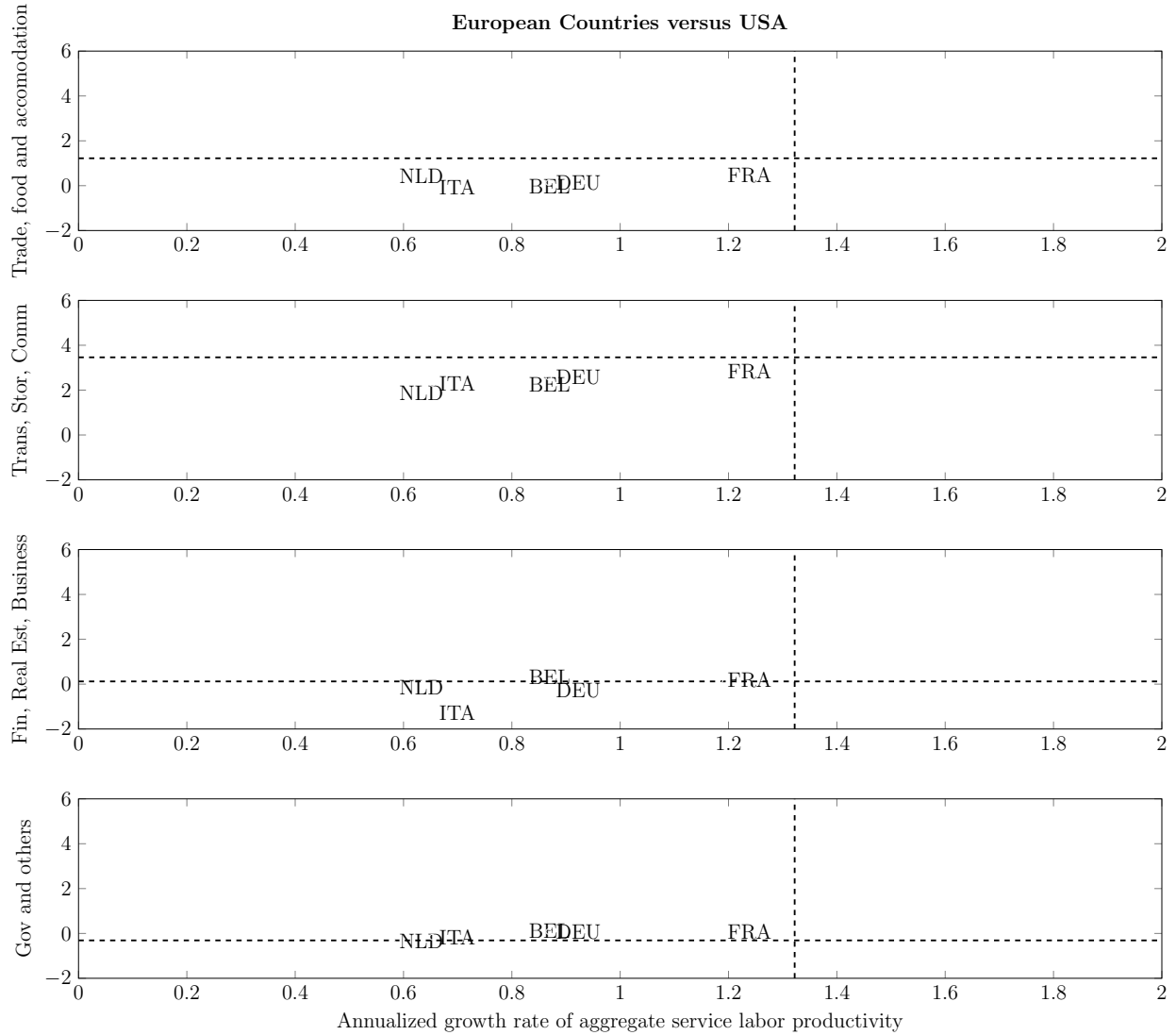


Figure 3.4: Aggregate service labor productivity is value added per employee, whereas service sub-sectoral labor productivity is value added per employee in each sub-sector. Annualized percentage growth rates during the sample period (1978-2010) are given for each country. The horizontal lines indicate the services sub-sectoral growth rates observed in the United States, and the vertical line indicates the aggregate service sector labor productivity growth rate of the United States.

Figure 3.4 illustrates that the labor productivity growth is the highest in TSC and second in TFA, being basically null in FRB and GO in all countries. This shows that service's labor productivity growth happens only in TFA and TSC. In addition, the figure also shows that the European countries have lower labor productivity growth than the US in TFA and TSC. This suggests that the lack of catch up in the European countries comes from lack of

catch up in TFA and TSC. For example, France that has the growth in labor productivity in TSC and TFA closest to the US has also the closest rate of growth rate in the aggregate service labor productivity at approximately 1.2%, while countries that were far in these same sub-sectors such as Italy and Netherlands had the poorest performance relative to the US in service aggregate labor productivity.

Motivated by the change in trend in the relative performance of the European countries relative to the US (with the exception of Netherlands) we analyse the annualized growth rate of labor productivity for each sub-sector pre and post 1995. In Figure 3.5 we start by plotting the pre 1995 scatter plot. It is interesting that the catch up in output was driven also by catching up in the service sector. Besides Netherlands, all countries had a better performance in service's labor productivity growth than the US. Breaking down the service sector, the good relative performance in services for that period seems to come from outperforming the US in FRB and GO while keeping up with the US in TFA and TSC; contrary to what was observed when looking at the entire sample period.

Somewhere in the 90's, the process of catch up in services was halted in the European countries. Figure 3.6 shows that for the post 1995 period, all European countries were lagging behind in service productivity, with average labor productivity of the European countries being less than half of that of the US. Moreover, the FRB that was a source of catch up in services pre 1995 became a source of divergence post 1995. The GO was the only sub-sector that did not suffer any major change and the productivity were null during the entire period and in the sub-periods as well.

Figures 3.5 and 3.6 also illustrate that the change in trend in the relative performance in labor productivity was carried by both increase in the US labor efficiency and a reduction in the European countries efficiency. The US tremendously increased its labor productivity in FRB, going from negative labor productivity growth rate pre 1995 to a 2% growth rate in post 1995. In addition, the US also improved 1 percentage point in productivity growth rate in TFA and TSC. At the same time, all the European countries that enjoyed a growth rate above 1% in service sector productivity pre 1995, dropped their rate of labor productivity growth in services to less than 1% post 1995.

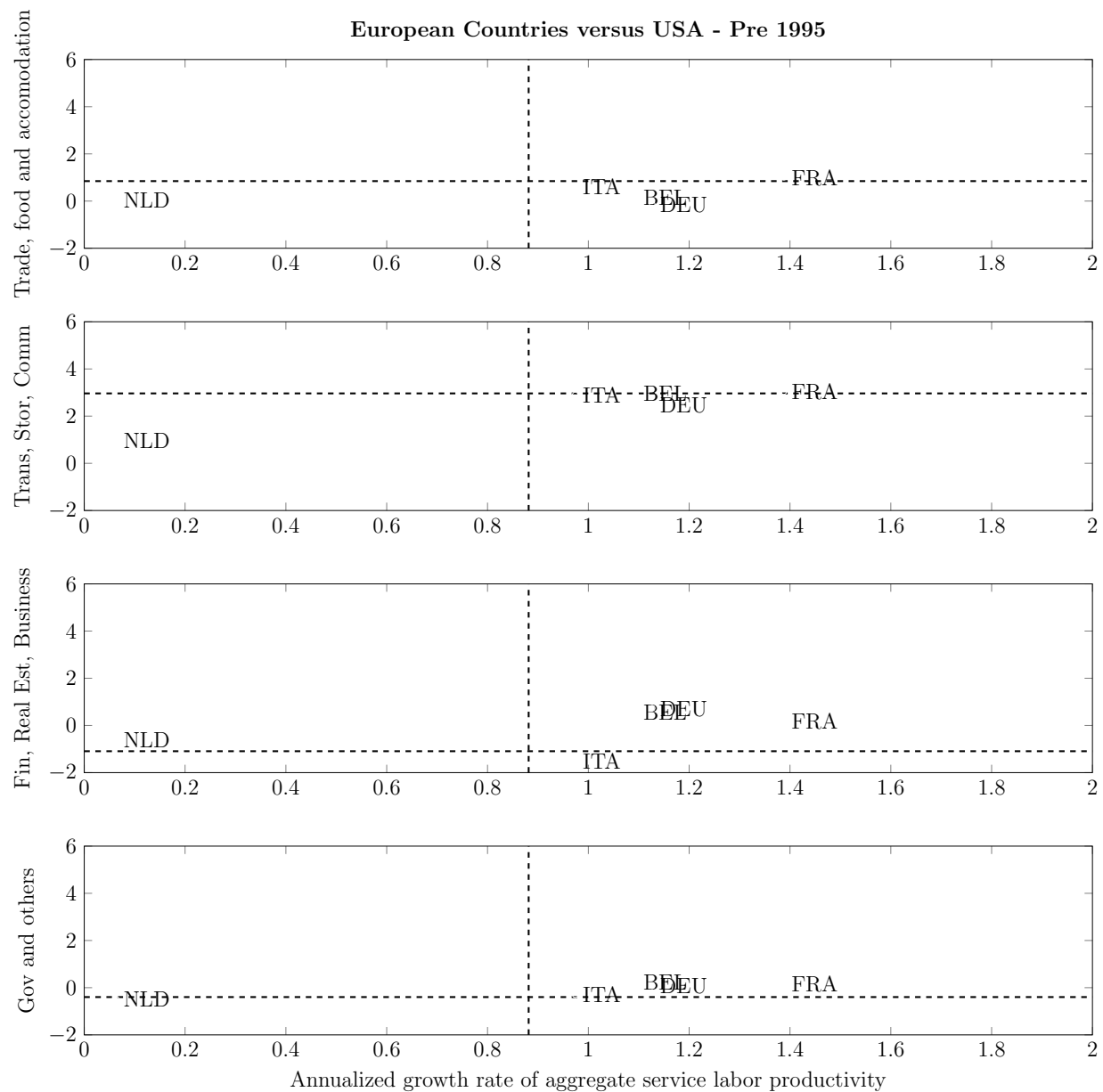


Figure 3.5: Aggregate service labor productivity is value added per employee, whereas service sub-sectoral labor productivity is value added per employee in each sub-sector. Annualized percentage growth rates during the sample period (1978-1995) are given for each country. The horizontal lines indicate the services sub-sectoral growth rates observed in the United States, and the vertical line indicates the aggregate service sector labor productivity growth rate of the United States.

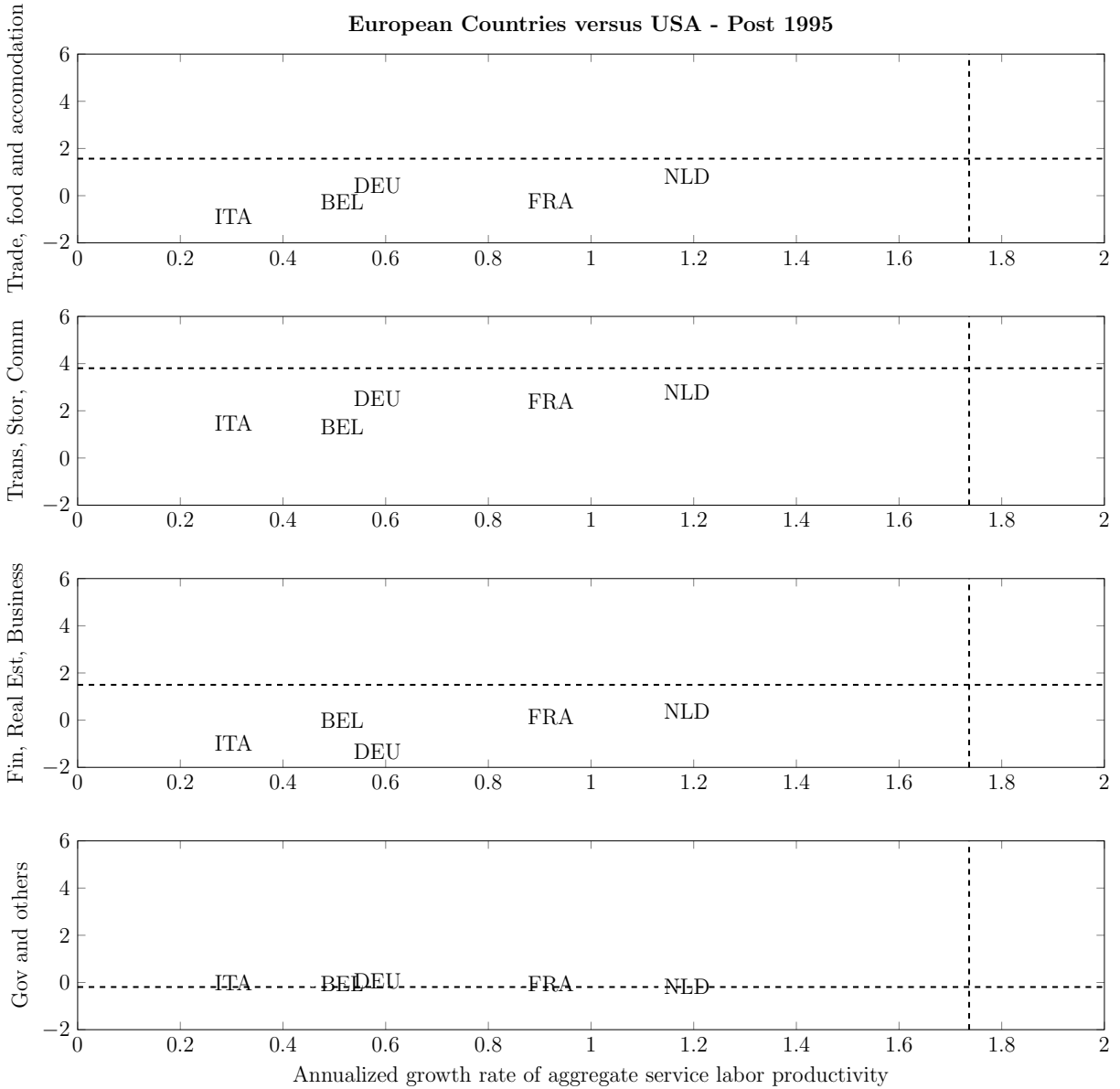


Figure 3.6: Aggregate service labor productivity is value added per employee, whereas service sub-sectoral labor productivity is value added per employee in each sub-sector. Annualized percentage growth rates during the sample period (1995-2010) are given for each country. The horizontal lines indicate the services sub-sectoral growth rates observed in the United States, and the vertical line indicates the aggregate service sector labor productivity growth rate of the United States.

3.3 Theoretical Framework

We propose an extension to the structural transformation model of Duarte and Restuccia (2010) by adding a layer of disaggregation in the service sector. The objective of this extended model is to study how each service sub-category affected the aggregate labor productivity.

Following Duarte and Restuccia (2010) and Rogerson (2008), two forces drive the allocation of labor across different sectors²: non-homothetic preferences (Kongsamut et al. (2001)) and substitution effect due to different productivity growth rates across sectors (Ngai and Pissarides (2007)). However, the labor reallocation across service sub-categories is driven by substitution effect only.

3.3.1 Baseline Structural Transformation Model

The baseline model is a replica of Duarte and Restuccia (2010). Three goods are produced at each period: agriculture, manufacturing and service. The production technology of each sector is given by:

$$Y_i = A_i L_i, \quad i \in \{a, m, s\} \quad (3.1)$$

where Y_i is output in sector i , L_i is labor input in sector i , and A_i is a sector-specific technology parameter. Here, A_i resumes all the factors that could affect labor productivity such as information technology³ and capital. We assume perfect competition and a continuum of homogeneous firms. In each period, given output price p_i and wage w , a representative firm in sector i faces the following problem:

$$\max_{L_i \geq 0} \{p_i A_i L_i - w L_i\} \quad (3.2)$$

The economy is populated by an infinitely lived representative household of constant

²For a detailed treatment of these two forces see Herrendorf et al. (2013).

³The EU KLEMS data has some information regarding the usage of information technology by each sector. In future work we want to explore empirically how this affects the labor productivity in each service sub-sector.

size one. The household is endowed with L units of time each period, which are supplied inelastically to the market. We associate L with being employed in the data. The household has preferences over consumption goods as follows:

$$\max_{c_i} \left\{ a \log (c_a - \bar{a}) + (1 - a) \frac{1}{\rho} \log [bc_m^\rho + (1 - b)(c_s + \bar{s})^\rho] \right\} \quad (3.3)$$

s.t.

$$p_a c_a + p_m c_m + p_s c_s = wL$$

where $\bar{a} > 0$ is a subsistence level of agricultural goods. These preferences are important in the realm of the development literature and it has been highlighted as a quantitatively important feature leading to the movement of labor away from agriculture in the process of structural transformation⁴. And where $\bar{s} > 0$, $b \in (0, 1)$, and $\rho < 1$. The \bar{a} , subsistence level of agricultural goods, and the \bar{s} , negative subsistence level of service goods, imply that preferences are non-homothetic preferences. For $\bar{s} > 0$, these preferences imply the income elasticity of service goods is greater than one. The negative subsistence consumption level \bar{s} implies that at low levels of income the households allocate less resources to the production of services, while when at high levels of income the reverse is true. The parameter \bar{s} can also be interpreted as a constant level of production of service goods at home.

The market clears each period whereby the total demand for labor equals the exogenous supply of labor, and consumption of each good equals supply.

$$L_a + L_m + L_s = L \quad (3.4)$$

$$c_a = Y_a, \quad c_m = Y_m, \quad c_s = Y_s \quad (3.5)$$

A competitive equilibrium in this economy is a set of prices $\{p_a, p_m, p_s\}$, allocations

⁴See, for instance, Echevarria (1997) , Laitner (2000) , Kongsamut et al. (2001) , Gollin et al. (2002), and Restuccia et al. (2008).

$\{c_a, c_m, c_s\}$ for the household, and allocations $\{L_a, L_m, L_s\}$ for firms such that (i) given prices, firm's allocations $\{L_a, L_m, L_s\}$ solve the firm's problem in (3.2); (ii) given prices, household's allocations $\{c_a, c_m, c_s\}$ solve the household's problem in (3.3); and (iii) markets clear: equations (3.4) and (3.5) hold.

The first order conditions associated with the firms optimization problem imply that when the wage is normalized to 1, the good prices are given by:

$$p_i = \frac{1}{A_i} \quad (3.6)$$

The good prices are inversely related with labor productivity and are affected by the productivity only. And the first order conditions of the households problem using the price solution imply that the labor share in agriculture is given by:

$$L_a = (1 - a) \frac{\bar{a}}{A_a} + a \left(L + \frac{\bar{s}}{A_s} \right) \quad (3.7)$$

The households first order conditions also imply that the labor share of manufacturing is given by:

$$L_m = \frac{(L - L_a) + \bar{s}/A_s}{1 + x} \quad (3.8)$$

where,

$$x = \left(\frac{b}{1 - b} \right)^{1/(\rho-1)} \left(\frac{A_m}{A_s} \right)^{\rho/(\rho-1)}$$

Finally using market clearing in the labor market, the labor share in services is given by:

$$L_s = 1 - L_a - L_m \quad (3.9)$$

3.3.2 Extending the Baseline Structural Transformation Model

We extend the baseline model by including additional four service sub-sectors in the economy. Hence, now we have production of goods that follows the same production technology as

before. Hence, producers of these four service sub-categories face the same problem as in the previous section. Preferences, with respect to agriculture, manufacturing and service goods are the same. However, now the service good is going to be a composite good of the four sub-service sector goods given by the following CES aggregate:

$$c_s = \left[\sum_{j=1}^4 c_{sj}^\sigma \right]^{1/\sigma} \quad (3.10)$$

where $\sigma < 1$, being the parameter that controls the elasticity of substitution between these four service goods. Hence, now the households will have a two stages optimization. In the first one, agents face the optimization problems of the previous section and in the second stage they will solve for each individual service good:

$$\max_{c_{sj}} \left\{ \left[\sum_{j=1}^4 c_{sj}^\sigma \right]^{1/\sigma} \right\} \quad (3.11)$$

s.t.

$$\sum_{j=1}^4 p_{sj} c_{sj} = \frac{p_s c_s}{wL}$$

where p_s , the price of the service composite good is given by the following price aggregate:

$$p_s = \left[\sum_{j=1}^4 p_{sj}^{\sigma/(\sigma-1)} \right]^{(\sigma-1)/\sigma} \quad (3.12)$$

Market clearing will be an expanded version of the baseline model given by:

$$L_a + L_m + L_s = L \quad (3.13)$$

$$L_s = \sum_{j=1}^4 L_{sj} \quad (3.14)$$

$$c_a = Y_a, \quad c_m = Y_m, \quad c_s = Y_s \quad (3.15)$$

$$c_{s1} = Y_{s1}, \quad c_{s2} = Y_{s2} \quad c_{s3} = Y_{s3} \quad c_{s4} = Y_{s4} \quad (3.16)$$

The first order conditions associated with the firms of the service sub-sector again imply that prices are going to be inversely related with the labor productivity of each individual sub-sector.

$$p_{sj} = \frac{1}{A_{sj}} \quad (3.17)$$

And the households second stage first order conditions imply that the consumption of each service is given by:

$$c_{sj} = c_s \left[\frac{p_s}{p_{sj}} \right]^{1/(1-\sigma)} \quad (3.18)$$

Using market clearing conditions and 3.17 one finds that the sub-sector labor shares are given by:

$$L_{sj} = L_s \left[\frac{A_{sj}}{A_s} \right]^{\frac{\sigma}{(1-\sigma)}} \quad (3.19)$$

Note that only the substitution effect is at work in the structural transformation of the service sub-sectors. In future work, our objective is to calibrate ρ to match the labor shares of the service sub-sectors in the US. This will allow us to use the model to pin down the initial labor productivity level of each individual service sub-sector across countries, thus allowing for important comparisons of productivity in the service sectors between different countries. This is an important feature as there is no service sub-sector value added PPP adjusted. This could potentially overcome some of the problems stated in Baily and Solow (2001).

3.4 Labor Market Regulation and Service Sector Labor Productivity

In this section, we show our preliminary results for the empirical investigation of the effect of labor market regulation on service sector labor productivity. Table 3.1 show the effect of labor market regulation indicators (OECD) on value added per worker (EU KLEMS). These estimates are from a balanced panel from 1985-2010 using fixed effects. We find that an increase in the notice period, which can be interpreted as an increase in labor market rigidity, is negatively correlated with service sector productivity. Moreover, with the exception of GO, is consistent with each individual sub-sector. However, the intensity of the negative correlation is different, with TSC and TFA being the most affected by an increase in the notice period. When the notice period increases, a firm that wants to fire an unproductive worker needs to stay with the worker longer, thus decreasing the overall productivity. The same idea goes along the lines of an increase in the trial period. Even if a firm has a poor evaluation of a new worker, with a rise in the trial period, it needs to wait longer to finally fire the worker which again decreases overall productivity. Nevertheless, it is interesting to note that the effect is affects all sub-categories now.

We find preliminary indirect evidence of experience on labor productivity since an increase in the limits to fixed-term employment are negatively correlated with labor productivity. In other words, when the limits to fixed-term employment increase, firms need to use more temporary labor force and this seems to be negatively correlated with labor productivity. Hence, fixed contracts that are associated with workers that stay longer on the jobs are associated with high productivity, thus implying that workers with higher experience are more productive.

	<i>Total Services</i>	<i>FRB Services</i>	<i>GO Services</i>	<i>TFA Services</i>	<i>TSC Services</i>
Notice Period (9 month tenure)	-0.916*** (0.295)	-0.008 (0.207)	-0.874** (0.374)	-1.677*** (0.582)	-3.360*** (0.766)
Severance (9 month tenure)	1.297* (0.689)	1.974*** (0.485)	-0.158 (0.875)	2.779** (1.362)	2.642 (1.792)
Def. justified dismissal	1.101** (0.547)	0.836** (0.385)	-1.008 (0.695)	-1.150 (1.081)	7.503*** (1.422)
Trial period	-1.589*** (0.290)	-1.066*** (0.204)	-1.685*** (0.369)	-2.246*** (0.574)	-1.954** (0.755)
Limits to fixed-term empl.	-0.972*** (0.139)	-0.481*** (0.098)	-1.267*** (0.176)	-1.444*** (0.274)	-1.257*** (0.361)
Max. succ. fixed-term empl.	0.472*** (0.142)	0.183* (0.100)	0.207 (0.180)	-0.209 (0.281)	2.179*** (0.369)
Max. cumul. duration fixed-term	1.607*** (0.310)	0.936*** (0.218)	1.959*** (0.394)	1.663*** (0.613)	3.246*** (0.806)
Cases for TWA empl.	-1.160*** (0.357)	-0.572** (0.251)	0.394 (0.453)	-1.918*** (0.706)	-4.651*** (0.928)
Restriction on TWA renewal	2.512*** (0.611)	1.878*** (0.430)	2.327*** (0.776)	4.874*** (1.208)	2.453 (1.589)

Table 3.1: The effect of labor market regulation indicators (OECD) on value added per worker (EU KLEMS). These estimates are from a balanced panel for the 1985-2010 period using fixed effects.

3.5 Conclusion

We conclude that both the structural transformation within the service sector and the labor market regulation help understanding why European countries have lower service labor productivity than the US. First, although the trend of labor allocation is similar in service sub-sectors, the levels of labor shares are different. At the same time, the sub-service sector's labor productivity are remarkably different between Europe and US. European countries underperformed relative to the US in TFA (trade, food and accommodation) and TSC (transportation, storage and communication) and outperformed the US in GO (government and others, including health, education, personal and social services). Second, an extended

version of Duarte and Restuccia (2010) is proposed in order to quantify the relative importance of each service sub-sector in the aggregate service sector labor productivity. In future work, we will calibrate the model and use it to get the initial productivity levels of each service sub-sector, and perform counterfactual exercises to analyse the relative importance of each sub-sector in the aggregate service labor sector productivity. Finally, preliminary empirical work suggests that labor market regulations such as increases in the notice period are negatively correlated with service sector productivity and seem to affect relatively more TSC and TFA (the most productive service sub-sectors).

APPENDIX A

CHAPTER 1 APPENDIX

I - Figures

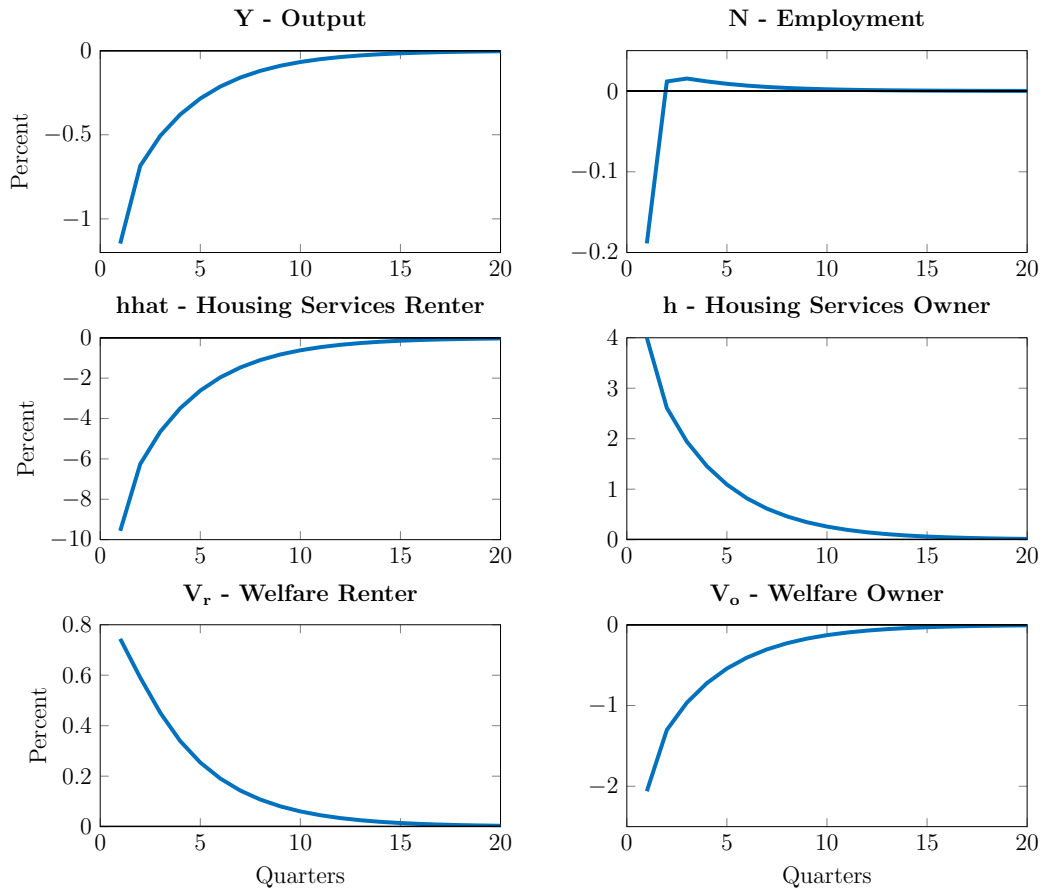


Figure A.1: Impulse-Response functions for other variables of interest for the benchmark model where the Taylor rule targets CPI. Each graph shows percentage response of one of the model's variables to a one-standard-deviation shock in monetary policy.

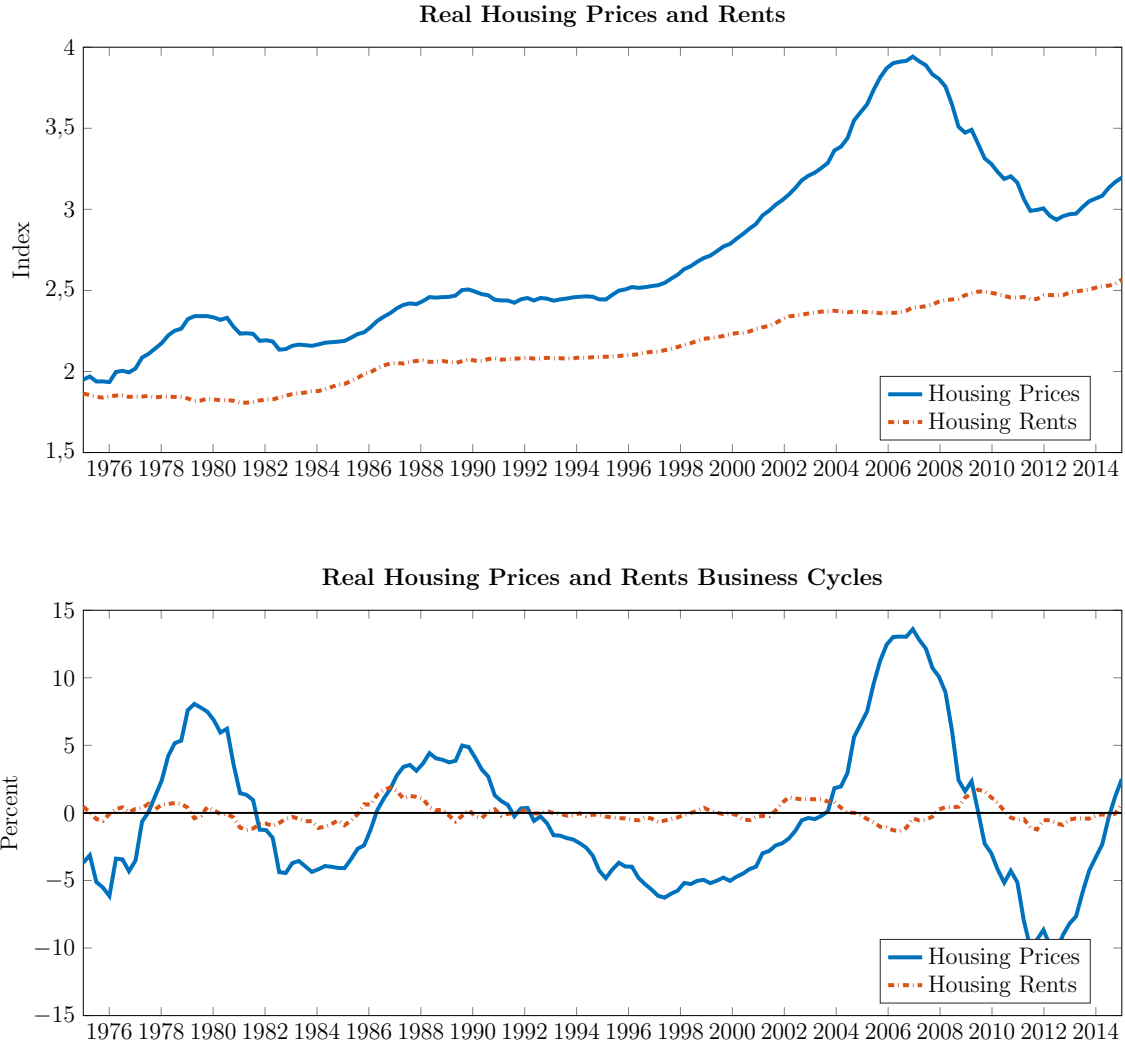


Figure A.2: Real Housing Prices and Rents from 1975 to 2015 and business cycles extracted with a HP filter with parameter λ set to 36000 and 1600 from housing prices and housing rents, respectively. The higher λ for housing prices is justified by the fact that they have long cycles and are more volatile than output.

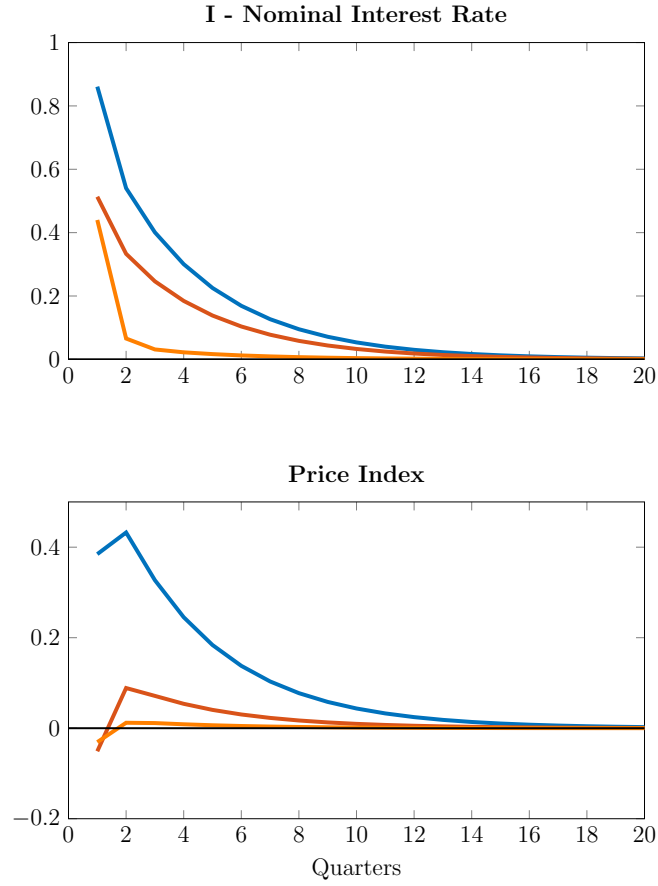


Figure A.3: Impulse-Response functions for main variables of interest for the benchmark model where the Taylor rule targets CPI (blue) *versus* alternative setting when Taylor rule targets PCE (red) and composite CPI (yellow).

II - Value Function Optimization

There is one individual state variable a and three aggregate state variables in the economy $\epsilon, \bar{\rho}$. Since, the heterogeneity is *iid*, the subscript i in the value function can be removed as the ρ_i integrates out.

$$V = \max_{rent, own} (V_{rent}(a; \epsilon, \bar{\rho}), V_{own}(a; \epsilon, \bar{\rho}) - \rho^i)$$

When the households decide to own a house, their problem is to:

$$\max_c V_{own}(a; \epsilon, \bar{\rho}) = u(c) + \beta(\gamma V_{own}(a'; \epsilon', \bar{\rho}') + (1 - \gamma)V(a'; \epsilon', \bar{\rho}'))$$

Using the equilibrium condition (9) we have that:

$$V_{rent}(a; \epsilon, \bar{\rho}) = V_{own}(a; \epsilon, \bar{\rho}) - \bar{\rho} \quad (\text{A.1})$$

Hence, replacing this condition we have the following,

$$V_{own}(a; \epsilon, \bar{\rho}) = u(c) + \beta(\gamma V_{own}(a'; \epsilon') + (1 - \gamma)(V_{own}(a'; \epsilon', \bar{\rho}') - \bar{\rho}')) \quad (\text{A.2})$$

$$V_{own}(a; \epsilon, \bar{\rho}) = u(c) + \beta(V_{own}(a'; \epsilon', \bar{\rho}')) - \beta(1 - \gamma)\bar{\rho}' \quad (\text{A.3})$$

Given that $\bar{\rho}$ is an aggregate state and is given to the household, it will not affect the household's optimization problem. The same proof can be constructed to the renter's optimization problem.

When the households decide to rent a house, their problem is to:

$$\max_{\hat{c}} V_{rent}(a; \epsilon, \bar{\rho}) = u(\hat{c}) + \beta(\gamma V_{rent}(a'; \epsilon', \bar{\rho}') + (1 - \gamma)V(a'; \epsilon', \bar{\rho}'))$$

Using the equilibrium condition (9) we have that:

$$V_{rent}(a; \epsilon, \bar{\rho}) = V_{own}(a; \epsilon, \bar{\rho}) - \bar{\rho} \quad (\text{A.4})$$

Hence, replacing this condition we have the following,

$$V_{rent}(a; \epsilon, \bar{\rho}) = u(\hat{c}) + \beta(\gamma V_{rent}(a'; \epsilon') + (1 - \gamma)(V_{rent}(a'; \epsilon', \bar{\rho}')))$$

Which means that:

$$V_{rent}(a; \epsilon, \bar{\rho}) = u(\hat{c}) + \beta(V_{rent}(a'; \epsilon', \bar{\rho}'))$$

APPENDIX B

CHAPTER 3 APPENDIX

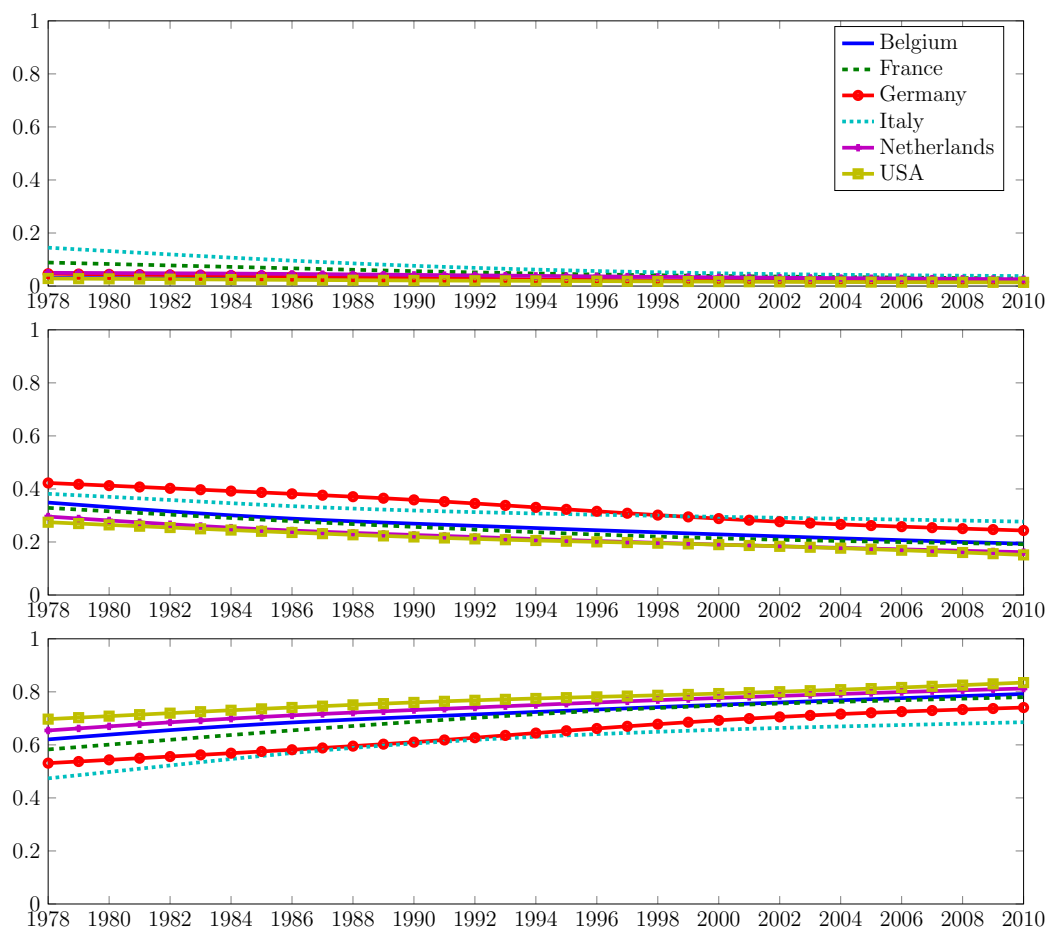


Figure B.1: Aggregate service labor productivity is value added per employee, whereas service sub-sectoral labor productivity is value added per employee in each sub-sector. Annualized percentage growth rates during the sample period (1978-2010) are given for each country. The horizontal lines indicate the services sub-sectoral growth rates observed in the United States, and the vertical line indicates the aggregate service sector labor productivity growth rate of the United States.

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